ENGINE 3

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SPECIFICATIONS 3.1

GENERAL		
Type	2 cylinder, air cooled, four-stroke 45 Degree V-twin	
Horsepower (ft-lbs)	101 @ 6200 RPM	
Torque (ft-lbs)	90 @ 5500 RPM	
Compression ratio	10.0 to 1	
Bore	3.498 in.	88.849 mm
Stroke	3.8125 in.	96.838 mm
Engine displacement	73.4 cu. in.	1203 cc
Oil tank capacity with filter change	2.5 quarts	2.37 liters

ENGINE IGNITION SPECIFICATIONS		
Type	Sequential, non waste spark	
Regular idle	850-1050 RPM	
Spark plug size	12 mm	
Spark plug type	Harley-Davidson No. 6R12	
Spark plug gap	0.038-0.043 in.	0.97-1.09 mm
Spark plug torque	11-18 ft-lbs	15-24 Nm

NOTE

Service wear limits are given as a guideline for measuring components that are not ***new****. For measurement specifications not given under SERVICE WEAR LIMITS, see NEW COMPONENTS.*

CAMSHAFT SPECIFICATIONS	
Lift @ valve (TDC) Intake/Exhaust	0.211 in./0.191 in.
Duration @ 0.053 lift Intake/Exhaust	256°/256°
Timing @ 0.053 lift Open/Close	Intake: 28° BTDC/48° ABDC Exhaust: 52° BBDC/24° ATDC

VALVE		NEW COMPONENTS		SERVICE WEAR LIMITS	
Fit in guide	Exhaust	0.0015-0.0033 in.	0.0381-0.0838 mm	0.0040 in.	0.1016 mm
	Intake	0.008-0.0026 in.	0.203-0.0660 mm	0.0035 in.	0.0889 mm
Seat width		0.040-0.062 in.	1.016-1.575 mm	0.090 in.	2.286 mm
Stem protrusion from cylinder valve pocket		1.975-2.011 in.	50.165-51.079 mm	2.031 in.	51.587 mm

OUTER VALVE SPRING		NEW COMPONENTS		SERVICE WEAR LIMITS	
Free length		2.105-2.177 in.	53.467-55.296 mm	2.105 in. (min)	53.467 mm (min)
Intake	1.751-1.848 in. (closed)	72-92 lbs	33-42 kg		
	1.286-1.383 in. (open)	183-207 lbs	83-94 kg		
Exhaust	1.751-1.848 in. (closed)	72-92 lbs	33-42 kg		
	1.332-1.429 in. (open)	171-195 lbs	78-88 kg		

INNER VALVE SPRING		NEW COMPONENTS		SERVICE WEAR LIMITS	
Free length		1.926-1.996 in.	48.920-50.698 mm	1.926 in. (min)	48.920 mm (min)
Intake	1.577-1.683 in. (closed)	38-49 lbs	17-22 kg		
	1.112-1.218 in. (open)	98-112 lbs	44-51 kg		
Exhaust	1.577-1.683 in. (closed)	38-49 lbs	17-22 kg		
	1.158-1.264 in. (open)	91-106 lbs	41-48 kg		

ROCKER ARM	NEW COMPONENTS		SERVICE WEAR LIMITS	
Shaft fit in bushing (loose)	0.0005-0.0020 in.	0.0127-0.0508 mm	0.0035 in.	0.0889 mm
End clearance	0.003-0.013 in.	0.076-0.330 mm	0.025 in	0.635 mm
Bushing fit in rocker arm (tight)	0.004-0.002 in.	0.102-0.0559 mm		
Rocker arm shaft fit in rocker cover (loose)	0.0007-0.0022 in.	0.018-0.056 mm	0.0035 in.	0.0889 mm

PISTON		NEW COMPONENTS		SERVICE WEAR LIMITS	
Compression ring gap (top and 2nd)		0.007-0.020 in.	0.178-0.508 mm	0.032 in.	0.813 mm
Oil control ring rail gap		0.009-0.052 in.	0.229-1.321 mm	0.065 in	1.651 mm
Compression ring side clearance	Top	0.0020-0.0045 in.	0.0508-0.1143 mm	0.0065 in.	0.1651 mm
	2nd	0.0016-0.0041 in.	0.0406-0.1041 mm	0.0065 in.	0.1651 mm
Oil control ring side clearance		0.0016-0.0076 in.	0.0406-0.1930 mm	0.0094 in.	0.2388 mm
Pin fit (loose, at room temperature)		0.00005-0.00045 in.	0.00127-0.01143 mm	0.00100 in.	0.02540 mm

CYLINDER HEAD	NEW COMPONENTS		SERVICE WEAR LIMITS	
Valve guide in head (tight)	0.0033-0.0020 in.	0.0838-0.0508 mm		
Valve seat in head (tight)	0.0035-0.0010 in.	0.0889-0.0254 mm		
Head gasket surface (flatness)	0.006 in. total	0.152 mm total	0.006 in. total	0.152 mm total

CYLINDER		NEW COMPONENTS		SERVICE WEAR LIMITS	
Taper				0.002 in.	0.051 mm
Out of round				0.003 in.	0.076 mm
Warpage (gasket surfaces)	Top			0.006 in.	0.152 mm
	Base			0.008 in.	0.203 mm
Bore diameter ± 0.0002 in.	Standard	3.4978 in.	88.8441 mm	3.5008 in.	88.9203 mm
	0.005 OS	3.502 in.	88.951 mm	3.5050 in.	89.0270 mm
	0.010 OS	3.507 in.	89.078 mm	3.5100 in.	89.1540 mm
OS=over size	0.020 OS	3.517 in.	89.332 mm	3.5200 in.	89.4080 mm
	0.030 OS	3.527 in.	89.586 mm	3.5300 in.	89.6620 mm

CONNECTING ROD	NEW COMPONENTS		SERVICE WEAR LIMITS	
Piston pin fit (loose)	0.00125-0.00175 in.	0.03175-0.04445 mm	0.00200 in.	0.05080 mm
Side play between flywheels	0.005-0.025 in.	0.127-0.635 mm	0.030 in.	0.762 mm
Fit on crankpin (loose)	0.0004-0.0017 in.	0.0102-0.0432 mm	0.0027 in.	0.0686 mm
Connecting rod race ID	1.6245-1.6250 in.	41.2623-41.2750 mm	1.6270 in.	41.3258 mm

TAPPET/HYDRAULIC LIFTER	NEW COMPONENTS		SERVICE WEAR LIMITS	
Fit in guide	0.0008-0.0020 in.	0.0203-0.0508 mm	0.0030 in.	0.0762 mm
Roller fit	0.0006-0.0010 in.	0.0152-0.0254 mm	0.0015 in.	0.0381 mm
Roller end clearance	0.008-0.022 in.	0.203-0.559 mm	0.026 in.	0.660 mm

OIL PUMP		NEW COMPONENTS		SERVICE WEAR LIMITS	
Oil pressure	1000 RPM	7-12 PSI	48-83 kN/m^2		
	2500 RPM	10-17 PSI	69-117 kN/m^2		
Shaft to pump clearance		0.0025 in.	0.0635 mm		
Feed/scavenge inner/outer gerotor clearance		0.003 in.	0.076 mm	0.004 in.	0.102 mm

GEARCASE	NEW COMPONENTS		SERVICE WEAR LIMITS	
Cam gear shaft in bushing (loose)	0.0007-0.0022 in.	0.0178-0.0559 mm	0.003 in.	0.076 mm
Cam gear shaft end play (min) (except rear intake)	0.005-0.024 in.	0.127-0.610 mm	0.025 in.	0.635 mm
Rear intake cam gear shaft end play (min)	0.006-0.024 in.	0.152-0.610 mm	0.040 in.	1.016 mm

FLYWHEEL		NEW COMPONENTS		SERVICE WEAR LIMITS	
Runout	Flywheels at rim	0.000-0.010 in.	0.000-0.254 mm	0.010 in.	0.254 mm
	Shaft at flywheel end	0.000-0.002 in.	0.000-0.051 mm	0.002 in.	0.051 mm
End play		0.001-0.005 in.	0.025-0.127 mm	0.005 in.	0.127 mm

SPROCKET SHAFT BEARING	NEW COMPONENTS		SERVICE WEAR LIMITS	
Outer race fit in crankcase (tight)	0.0004-0.0024 in.	0.0102-0.0610 mm		
Bearing inner race fit on shaft (tight)	0.0002-0.0015 in.	0.0051-0.0381 mm		

PINION SHAFT BEARINGS	NEW COMPONENTS		SERVICE WEAR LIMITS	
Pinion shaft jounal diameter	1.2496-1.2500 in.	31.7398-31.7500 mm	1.2496 in. (min)	31.7398 mm (min)
Outer race diameter in right crankcase	1.5646-1.5652 in.	39.7408-39.7561 mm	1.5672 in. (max)	39.8069 mm (max)
Bearing running clearance	0.00012-0.00088 in.	0.00305-0.02235 mm		
Fit in cover bushing (loose)	0.0023-0.0043 in.	0.0584-0.1092 mm	0.0050 in.	0.1270 mm

TORQUE VALUES

ITEM	TORQUE		NOTES
Anti-rotation screws **(2000 models)**	80-110 **in-lbs**	9.0-12.4 Nm	page 3-43
Crank pin nut **(1999 Models)**	150-185 ft-lbs	203.4-250.8 Nm	LOCTITE 620 RETAINING COMPOUND, page 3-71, page 3-72
Crankcase 1/4 in. screws	70-110 **in-lbs**	7.9-12.4 Nm	page 3-75
Crankcase 5/16 in. screws	15-19 ft-lbs	20.3-25.8 Nm	page 3-75
Cylinder head screws	7-9 ft-lbs then 13-15 ft-lbs then loosen and repeat torque sequence	9.5-12.2 Nm then 17.6-20.3 Nm then loosen and repeat torque sequence	special pattern to tighten, page 3-21
Cylinder studs	10-20 ft-lbs	13.6 -27.1Nm	special method to tighten, page 3-76
Front isolator to cylinder head bolt	73-78 ft-lbs	98.9-105.7 Nm	LOCTITE THREADLOCKER 262 (red), page 3-20
Gearcase cover screws	80-110 **in-lbs**	9.0-12.4 Nm	special pattern to tighten, page 3-59
Isolator bolt, front	100-110 ft-lbs	135.6-149.1 Nm	page 3-10
Isolator bolts, side	100-110 ft-lbs	135.6-149.1 Nm	LOCTITE THREADLOCKER 262 (red), page 3-10
Oil filter adapter	8-12 ft-lbs	10.8-16.3 Nm	LOCTITE THREADLOCKER 243 (blue), page 3-39
Oil pressure indicator switch	4-6 ft-lbs	5.4-8.1 Nm	page 3-39
Oil pump cover screws	125-150 **in-lbs**	14.1-16.9 Nm	TORX, page 3-38
Oil pump mounting screws	125-150 **in-lbs**	14.1-16.9 Nm	page 3-38
Pinion shaft nut	35-45 ft-lbs	47.5-61.0 Nm	LOCTITE THREADLOCKER 262 (red), page 3-50
Rocker box bolts	10-14 ft-lbs	13.6-19.0 Nm	page 3-22
Rocker box cover screws	10-14 ft-lbs	13.6-19.0 Nm	page 3-22
Rocker box screws	130-150 **in-lbs**	14.7-16.9 Nm	page 3-22
Rocker box to head bolts	15-19 ft-lbs	20.3-25.8 Nm	2 sizes, page 3-22
Swingarm mount block bolts, lower	68-75 ft-lbs	92.2-101.7 Nm	page 3-10
Swingarm mount block bolts, upper	41-45 ft-lbs	55.6-61.0 Nm	page 3-10
Tappet plate screw **(1999 Models)**	80-110 **in-lbs**	9.0-12.4 Nm	page 3-41
Tappet retainer screw **(1999 Models)**	11-15 ft-lbs	20.3-24.4 Nm	page 3-41
Tie bar bolts	30-33 ft-lbs	40.7-44.7 Nm	page 3-10

MODEL YEAR CHANGE

All 2000 Model Year Thunderstorm™ engines are equipped with **new** hydraulic lifters, redesigned lifter blocks, **new** gearcase cover and gasket, a straight, pressed-in crank pin and **new** low inertia flywheels.

GENERAL

The Thunderstorm™ high performance engine is a two-cylinder, four-cycle, air-cooled, overhead-valve V-twin. It has three major component assemblies.

Cylinder

The cylinder assembly includes cylinder head, valves, rocker arm cover, rocker arms and piston. Cylinders mount on the crankcase in a 45 degree "V" with both connecting rods connected to a single crank pin.

Thunderstorm engines have modified cylinder heads with a black finish and unique pistons.

Crankcase

The up-and-down motion of the piston in the cylinder is converted to circular motion in the crankcase. The multi-piece crankshaft consists of a crank pin mounted between two counterweighted flywheels, which rotate on two end shaft bearings. The lower end of the rear cylinder connecting rod is forked to fit around the single-end front cylinder connecting rod, allowing a single connecting rod crank pin connection to the flywheel.

Gearcase

The gearcase is located on the right side of the crankcase. The gearcase houses the gear train, which operates and times the valves and ignition. The cam gear train, consisting of four cam shafts with one cam lobe on each shaft, is gear driven. The engine valves are opened and closed through the mechanical linkage of hydraulic lifters, push rods and rocker arms. Hydraulic lifters, located in the lifter bores, automatically compensate for heat expansion to maintain the no-lash fit of valve train components. Hydraulic lifters and pushrods transmit the cam action to the valve linkage. Valve timing is obtained by aligning timing marks when installing cam gears.

Ignition spark is produced by the operation of a microprocessor-controlled electronic control module (ECM), ignition coil and spark plugs. Spark timing is determined by a trigger rotor, magnetic sensing unit and the ECM.

The trigger rotor has six openings which time the cylinders and communicate engine speed to the ECM.

The spark plugs fire independently during the compression stroke on each cylinder (no waste spark).

FUEL

Gasoline/alcohol Blends

Buell motorcycles were designed to obtain the best performance and efficiency using unleaded gasoline (91 pump octane or higher). Some fuel suppliers sell gasoline/alcohol blends as a fuel. The type and amount of alcohol added to the fuel is important.

- DO NOT USE GASOLINES CONTAINING METHANOL. Using gasoline/methanol blends will result in starting and driveability deterioration and damage to critical fuel system components.
- ETHANOL is a mixture of 10% ethanol (Grain alcohol) and 90% unleaded gasoline. Gasoline/ethanol blends can be used in your motorcycle if the ethanol content does not exceed 10%.
- Gasolines containing ETHER: Gasoline/ether blends are a mixture of gasoline and as much as 15% ether. Gasoline/ether blends can be used in your motorcycle if the ether content does not exceed 17%.
- REFORMULATED OR OXYGENATED GASOLINES (RFG): "Reformulated gasoline" is a term used to describe gasoline blends that are specifically designed to burn cleaner than other types of gasoline, leaving fewer "tailpipe" emissions. They are also formulated to evaporate less when you are filling your tank. Reformulated gasolines use additives to "oxygenate" the gas. Your motorcycle will run normally using this type of gas. Buell recommends you use it when possible, as an aid to cleaner air in our environment.

Because of their generally higher volatility, these blends may adversely affect the starting, driveability and fuel efficiency of your motorcycle. If you experience these problems, Buell recommends you operate your motorcycle on straight, unleaded gasoline.

LUBRICATION

The engine has a force-feed (pressure) type oiling system, incorporating oil feed and return pumps in one pump body, with one check valve on the oil feed side. The feed pump forces oil to the engine, lubricating lower connecting rod bearings, rocker arm bushings, valve stems, valve springs, push rods and tappets. Cylinder walls, pistons, piston pins, timing gears and bushings and main bearings are lubricated by oil spray thrown off connecting rods and crankshaft, and by oil draining from each rocker box through an internal drain passage in each cylinder and each tappet guide. A small amount of oil is sprayed through an oil galley jet onto the rear intake cam gear in the gearcase; oil is transferred to the teeth of all the cam gears by way of the gear meshing action. The oil-scavenging section of the pump returns oil to the tank from the engine. See 3.7 LUBRICATION SYSTEM for more information.

ADJUSTMENT/TESTING

General

When an engine needs repair, it is not always possible to determine definitely beforehand whether repair is possible with only cylinder heads, cylinders and pistons disassembled or whether complete engine disassembly is required for crankcase repair.

Most commonly, only cylinder head and cylinder repair is needed (valves, rings, piston, etc.) and it is recommended procedure to service these units first, allowing engine crankcase to remain in frame.

See 3.3 STRIPPING MOTORCYCLE FOR ENGINE REPAIR to strip motorcycle for removal of cylinder heads, cylinders, and pistons.

After disassembling "upper end" only, it may be found that crankcase repair is necessary. In this situation, remove the engine crankcase from the chassis. See 3.3 STRIPPING MOTORCYCLE FOR ENGINE REPAIR.

CAUTION

If engine is removed from chassis, do not lay engine on primary side. Placing engine on primary side will damage clutch cable end fitting. If fitting is damaged, clutch cable must be replaced.

Symptoms indicating a need for engine repair are often misleading, but generally, if more than one symptom is present, possible causes can be narrowed down to make at least a partial diagnosis. An above-normal consumption of oil, for example, could be caused by several mechanical faults. See 1.27 TROUBLESHOOTING. However, when accompanied by blue-gray exhaust smoke and low engine compression, it indicates the piston rings need replacing. Low compression by itself, however, may indicate improperly seated valves, in addition to or in lieu of worn piston rings.

Most frequently, valves, rings, pins, bushings, and bearings need attention at about the same time. If the possible causes can be narrowed down through the process of elimination to indicate any one of the above components is worn, it is best to give attention to all of the cylinder head and cylinder parts.

Compression Test Procedure

Combustion chamber leakage can result in unsatisfactory engine performance. A compression test can help determine the source of cylinder leakage. Use CYLINDER COMPRESSION GAUGE (Part No. HD-33223-1).

A proper compression test should be performed with the engine at normal operating temperature when possible. Proceed as follows:

CAUTION

After completing the compression test(s), make sure that the throttle plate is in the closed position before starting engine. Engine will start at an extremely high RPM if throttle plate is left open.

1. Disconnect spark plug wires. Clean around plug base and remove plugs.
2. Connect compression tester to front cylinder.
3. With throttle plates in wide open position, crank engine continuously through 5-7 full compression strokes.
4. Note gauge readings at the end of the first and last compression strokes. Record test results.
5. Connect compression tester to rear cylinder.
6. Repeat Steps 3 and 4 on rear cylinder.
7. Compression is normal if final readings are 120 psi (827 kN/m^2) or more and do not indicate more than a 10 psi (69 kN/m^2) variance between cylinders. See Table 3-1.
8. Inject approximately 1/2 oz. (15 ml) of SAE 30 oil into each cylinder and repeat the compression tests on both cylinders. Readings that are considerably higher during the second test indicate worn piston rings.

Table 3-1. Compression Test Results

DIAGNOSIS	TEST RESULTS
Ring trouble	Compression low on first stroke; tends to build up on the following strokes but does not reach normal; improves considerably when oil is added to cylinder.
Valve trouble	Compression low on first stroke; does not build up much on following strokes; does not improve considerably with the addition of oil.
Head gasket leak	Same reaction as valve trouble.

Cylinder Leakage Test

The cylinder leakage test pinpoints engine problems including leaking valves, worn, broken or stuck piston rings and blown head gaskets. The cylinder leakage tester applies compressed air to the cylinder at a controlled pressure and volume, and measures the percent of leakage from the cylinder.

Use a CYLINDER LEAKDOWN TESTER (Part No. HD-35667A) and follow the specific instructions supplied with the tester.

The following are some general instructions that apply to Buell motorcycle engines:

1. Run engine until it reaches normal operating temperature.
2. Stop engine. Clean dirt from around spark plugs and remove spark plugs.
3. Remove air cleaner cover. Set throttle in wide open position.
4. Remove timing inspection plug from crankcase.
5. The piston, in cylinder being tested, must be at top dead center of compression stroke during test.
6. To keep engine from turning over when air pressure is applied to cylinder, engage transmission in fifth gear and lock the rear brake.
7. Following the manufacturer's instructions, perform a cylinder leakage test on the front cylinder. Make a note of the percent leakdown. Any cylinder with 12% leakdown, or more, requires further attention.
8. Listen for air leaks at intake, exhaust, head gasket and timing inspection hole. See Table 3-2.

NOTE

If air is escaping through valves, check push rod length.

9. Repeat procedure on rear cylinder.

CAUTION

After completing the compression test(s), make sure that the throttle plate is in the closed position before starting engine. Engine will start at an extremely high RPM if throttle plate is left open.

Table 3-2. Air Leakage Test

AIR LEAK LOCATION	POSSIBLE CAUSES
Manifold intake	Intake valve leaking.
Exhaust pipe	Exhaust valve leaking.
Timing inspection hole	Piston rings leaking. Worn or broken piston. Worn cylinder.
Head gasket	Leaking gasket.

Diagnosing Smoking Engine or High Oil Consumption

Perform COMPRESSION TEST PROCEDURE or CYLINDER LEAKAGE TEST as described previously. If further testing is needed, remove suspect head(s) and inspect the following:

- Valve guide seals.
- Valve guide-to-valve stem clearance.
- Gasket surface of both head and cylinder.
- Oil return passages for clogging.

DISASSEMBLING ENGINE FOR CYLINDER HEAD REPAIR

1. Lift and secure the motorcycle.
   a. Place vehicle on a lift and anchor front wheel in place. Raise lift so the top of the cylinder head is easy to access.
   b. Raise rear wheel off lift using REAR WHEEL SUPPORT STAND (Part No. B-41174).

⚠WARNING

To avoid accidental start-up of vehicle and possible personal injury, disconnect the battery cables before proceeding. Always disconnect the negative cable first. If the positive cable should contact ground with the negative cable installed, the resulting sparks may cause a battery explosion which could result in death or serious injury.

2. Disconnect **both** battery cables, negative cable first.

⚠WARNING

The gasoline in the fuel supply line downstream of the fuel pump is under high pressure (49 psi [338 kPa]). To avoid an uncontrolled discharge or spray of gasoline, always purge the system of high pressure gas before attaching fuel pressure gauge. Gasoline is extremely flammable and highly explosive. Inadequate safety precautions could result in death or serious injury.

3. Remove seat and fuel tank. See 4.34 FUEL TANK.
4. Remove air cleaner cover and backplate. See 4.39 AIR CLEANER.
5. Remove throttle body and manifold. See 4.38 THROTTLE BODY AND MANIFOLD.
6. Remove support bracket on left side of cylinder heads.
7. Remove exhaust header and muffler. See 2.35 EXHAUST SYSTEM.
8. Disconnect spark plug cables. Remove spark plugs.
9. If removing front cylinder, remove ignition coil (4.30 IGNITION COIL) and horn (7.22 HORN).

NOTE

At this stage, the lower rocker boxes, cylinder heads and cylinders may be removed. See 3.5 CYLINDER HEAD.

ENGINE CRANKCASE REPLACEMENT OR COMPLETE ENGINE REMOVAL

1. Perform the steps listed above. In addition, remove battery from frame.
2. See Figure 3-1. Place a floor hoist behind the lift. Attach straps to tail section and hoist. Raise hoist until straps tighten.

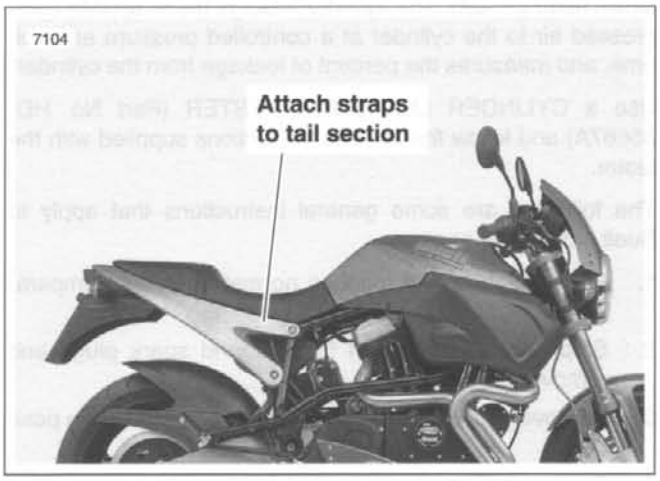


Figure 3-1. Floor Hoist

3. Detach clutch cable from handlebar lever.
4. Remove rear fender and lower belt guard. See 2.40 REAR FENDER.
5. Remove sprocket cover. See 2.38 SPROCKET COVER.
6. Detach rear brake caliper from caliper mount. See 2.15 REAR BRAKE CALIPER (1999 models) or 2.22 REAR BRAKE CALIPER (2000 models).
7. Detach belt from rear sprocket and remove rear wheel. See 2.7 REAR WHEEL.
8. Drain oil tank and remove oil filter. See 1.6 ENGINE LUBRICATION SYSTEM.
9. Detach hoses from oil tank fittings. See 3.9 OIL TANK.
10. Remove both rider footrest mounts from frame. See 2.36 FOOTRESTS (1999 Models) or 2.37 FOOTRESTS (2000 Models).
11. Remove both rear shock mounting bolts (metric).
12. Disconnect wiring. See Section 7.
    a. Disconnect neutral switch wire from crankcase.
    b. Unplug cam position sensor from wiring harness.
    c. Remove solenoid wire, battery positive cable and circuit breaker charging wire from starter motor.
    d. Locate voltage regulator connector near the oil pump. Disconnect from alternator stator.
    e. Detach wire from oil pressure indicator switch. See 3.10 OIL PRESSURE INDICATOR SWITCH.
13. See Figure 3-2. Place a wooden cradle underneath the crankcase.

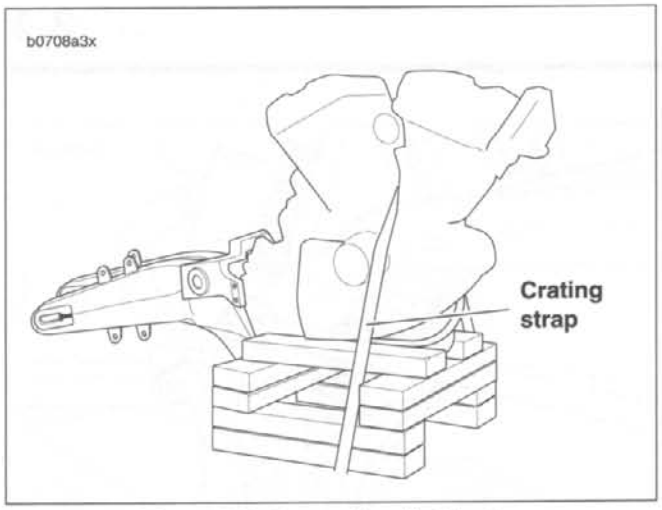


Figure 3-2. Supporting the Engine

14. Place a crating strap between the engine cylinders and around the lift. Tighten crating strap until snug.
15. See Figure 3-3. Remove engine ground strap (1) from swingarm mount block.
16. Detach remaining tie bars from frame.
    a. Remove rear tie bar using a swivel socket.
    b. See Figure 3-4. Detach front lower tie bar (1) and clutch cable clamp (3). Remove tie bar bolt (2), clutch cable clamp (3), washer (4) and locknut (5).
    c. Remove washer and nut to detach front upper tie bar (11) from isolator (8).
17. Detach front isolator (8). Remove front isolator bolt (6), nut (10), D-washer (9) and washer (7).
18. See Figure 3-3. Remove isolator bolt (7) and lockwasher (6) on each side.
19. Slowly raise floor hoist until rubber isolators (5) can be removed. Frame will rise while engine remains secured to lift by crating strap.

NOTE

Rubber isolators align with a frame mounted metal pin.

20. Raise frame and walk forward over and away from the engine.
21. If necessary, remove rear swingarm assembly. See 2.27 SWINGARM.
22. If necessary, detach swingarm mount block from powertrain by removing bolts (3, 4), washers and locknuts.

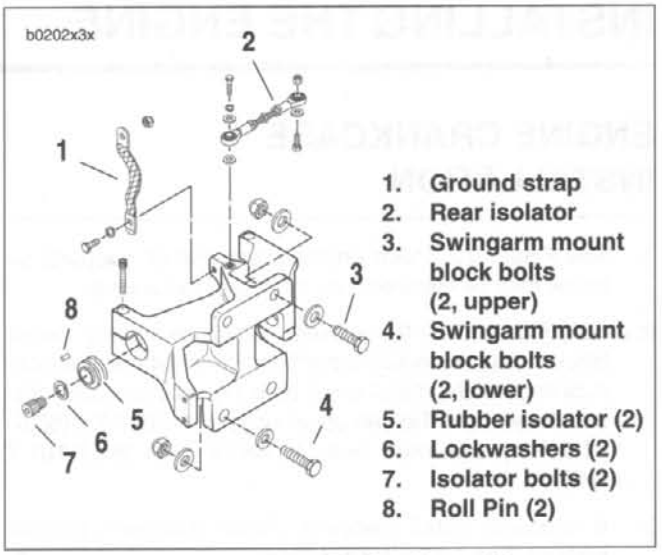


Figure 3-3. Rear Tie Bar Assembly

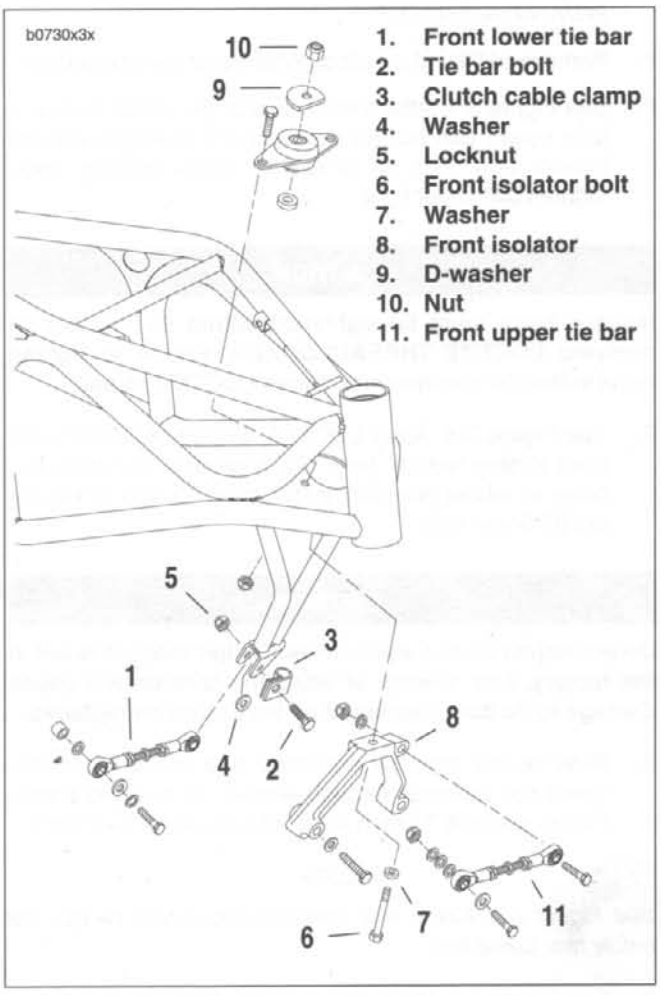


Figure 3-4. Front Tie Bar Assembly

ENGINE CRANKCASE INSTALLATION

1. See Figure 3-2. Place engine crankcase on supports so frame may be installed over the top of the engine.
2. See Figure 3-3. If removed, attach swingarm mount block to engine. Install upper bolts (3), washers and locknuts finger tight. Install lower bolts (4), washers and locknuts finger tight. Tighten upper bolts to 41-45 ft-lbs (55.6-61.0 Nm) and lower bolts to 68-75 ft-lbs (92.2-101.7 Nm).
3. If removed, install swingarm. Adjust swingarm bearing preload. See 2.27 SWINGARM.
4. If removed, install transmission mainshaft sprocket. See 6.13 TRANSMISSION INSTALLATION AND SHIFTER PAWL ADJUSTMENT.
5. Remove oil filter (if installed). Walk frame over powertrain.
6. See Figure 3-4. Attach front isolator (8). Install front isolator mount with bolt (6), washers (7), D-washer (9) and locknut (10). Flat on D-washer faces steering neck. Tighten bolt finger tight.

CAUTION

Isolator bolts must be tightened within 30 minutes of applying LOCTITE THREADLOCKER. Failure to tighten bolts within 30 minutes may cause LOCTITE to set.

7. See Figure 3-3. Apply LOCTITE THREADLOCKER 262 (red) to side isolator bolts (7). Align pins on frame into holes in rubber isolators. Install bolts (7) and lockwashers (6) finger tight.

CAUTION

Do not adjust tie bar assemblies. Tie bar tension is set at the factory. Any attempt at adjusting tension will cause damage to tie bars. Damaged tie bars must be replaced.

8. Rear tie bar must be horizontal and below frame tab. Insert bolt upwards through washer, tie bar and frame. Fasten with nut. Tighten to 30-33 ft-lbs (40.7-44.7 Nm).

NOTE

See Figure 3-5. Route wire harness above rear tie bar, but below rear brake line.

9. See Figure 3-4. Place clutch cable clamp (3) on front tie bar bolt (2). Clamp should hold cable on primary cover side of motor. Insert bolt from front through frame and install washer (4). Continue through tie bar (1) and frame. Install locknut (5) and tighten to 30-33 ft-lbs (40.7-44.7 Nm).
10. Attach front upper tie bar (11). Insert bolt through tie bar front isolator, and frame. Secure with nut and washer. Tighten to 30-33 ft-lbs (40.7-44.7 Nm).

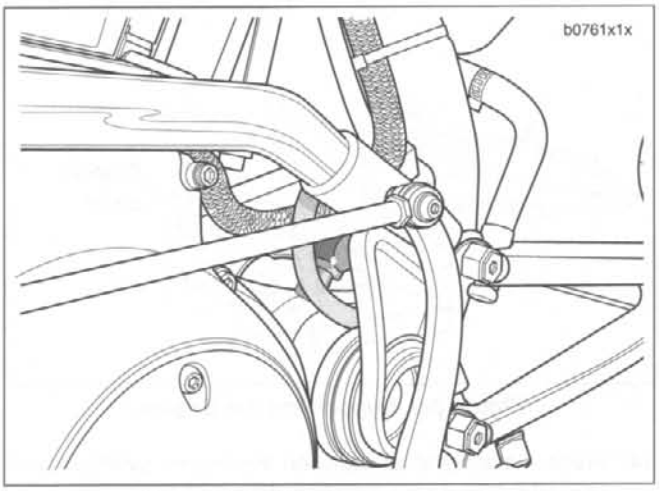


Figure 3-5. Wire Harness Routing

11. See Figure 3-3. Tighten the two side isolator bolts (7) to 100-110 ft-lbs (135.6-149.1 Nm).
12. See Figure 3-4. Tighten front isolator bolt (6) to 100-110 ft-lbs (135.6-149.1 Nm).
13. Connect hoses to oil tank. See 3.8 OIL HOSE ROUTING. Use **new** hose clamps.
14. Attach battery ground strap to swingarm mount block.
15. Attach clutch cable to handlebar lever.
16. Remove strap from between engine cylinders. Using a floor hoist, lift motorcycle by the frame and remove the wooden cradle from underneath the crankcase.
17. Install rear shock. See 2.28 REAR SHOCK ABSORBER.
18. Install rear wheel and attach secondary drive belt. See 2.7 REAR WHEEL. After rear wheel and belt are installed, remove floor hoist straps.
19. Install rear brake caliper. See 2.15 REAR BRAKE CALIPER (1999 models) or 2.22 REAR BRAKE CALIPER (2000 models).
20. Attach disconnected wires. See Section 7.
    a. Connect solenoid wire, circuit breaker charging wire and battery positive cable to starter.
    b. Connect voltage regulator connector to alternator stator wiring.
    c. Attach cam position sensor to wire harness.
    d. Connect neutral switch wire to crankcase.
    e. Attach oil pressure indicator switch wire.
21. Install rear fender and lower belt guard. See 2.40 REAR FENDER.
22. Install sprocket cover. See 2.38 SPROCKET COVER.
23. Install footrests. See 2.36 FOOTRESTS (1999 Models) or 2.37 FOOTRESTS (2000 Models).
24. Continue with the steps listed under ENGINE INSTALLATION AFTER CYLINDER HEAD REPAIR.

ENGINE INSTALLATION AFTER CYLINDER HEAD REPAIR

1. Install **new** oil filter, engine oil and primary chaincase fluid as necessary. See Section 1.
2. Install throttle body and manifold and support bracket. See 4.38 THROTTLE BODY AND MANIFOLD.
3. Install exhaust system. See 2.35 EXHAUST SYSTEM.
4. Install air cleaner assembly. See 4.39 AIR CLEANER.
5. If removed, install horn (7.22 HORN) and ignition coil (4.30 IGNITION COIL).
6. Install spark plugs and connect cables. See 1.20 SPARK PLUGS.

⚠WARNING

Always connect positive battery cable first. If the positive cable should contact ground with the negative cable installed, the resulting sparks may cause a battery explosion which could result in death or serious injury.

7. Install battery. Connect both battery cables, positive cable first.

⚠WARNING

After installing seat, pull upward on front of seat to be sure it is locked in position. If seat is loose, it could shift during vehicle operation and startle the rider, causing loss of control which could result in death or serious injury.

8. Install fuel tank, fuel tank cover and seat. See 4.34 FUEL TANK.
9. If engine crankcase installation was performed:
   a. Adjust rear belt deflection. See 1.13 REAR BELT DEFLECTION.
   b. Adjust rear shock spring preload. See 1.16 PRELOAD ADJUSTMENT.
   c. Adjust clutch lever. See 1.12 CLUTCH.
   d. Check rear brake pedal height. See 1.7 BRAKES (1999 Models) or 1.9 BRAKES (2000 Models).
10. Check all electrical components for proper operation.
11. Calibrate (re-zero) TPS. See 4.33 THROTTLE POSITION SENSOR

REMOVAL

Before removing the cylinder head assembly, see DISASSEMBLING ENGINE FOR CYLINDER HEAD REPAIR. The rocker arm covers and internal components must be removed before removing cylinder heads.

1. See Figure 3-6. Remove screws with washers (1) and fiber seals (2). Discard fiber seals.

CAUTION

All washers and fasteners used in the V^2_{TM} engine are hardened. Do not mix or replace hardened washers and fasteners with unhardened parts. Do not reuse fiber cover seals. These actions may result in accelerated wear and increased noise.

2. Remove upper (4) and middle (5) sections of rocker cover. Remove and discard gaskets (6, 7 and 8).
3. Rotate crankshaft until piston on head being repaired reaches top dead center of compression stroke.

NOTE

Both valves in the cylinder head will be closed when viewed through the spark plug hole.

4. Remove the two rocker arm retaining bolts (12) near the push rods.
5. Remove remaining hardware holding lower rocker cover to cylinder head in the following order.
   a. Remove two screws and washers (14).
   b. Remove three bolts and washers (15).
   c. Remove the remaining two rocker arm retaining bolts (13).
6. Remove lower rocker cover (18).

NOTE

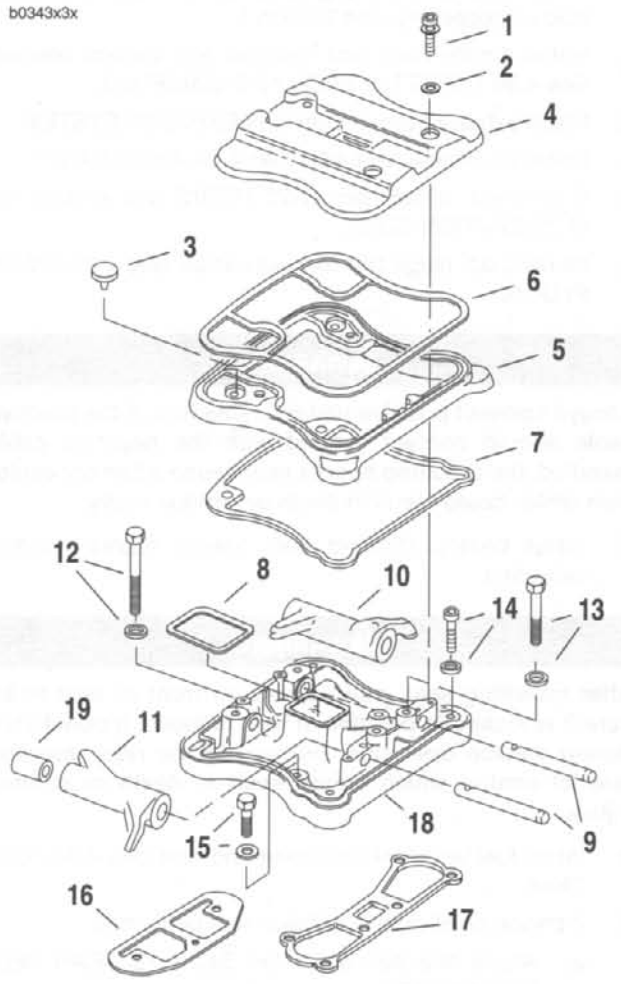
Remove lower rocker boxes as an assembly; then disassemble as required.

7. Mark the location and orientation (top/bottom) of each push rod. Remove push rods.

CAUTION

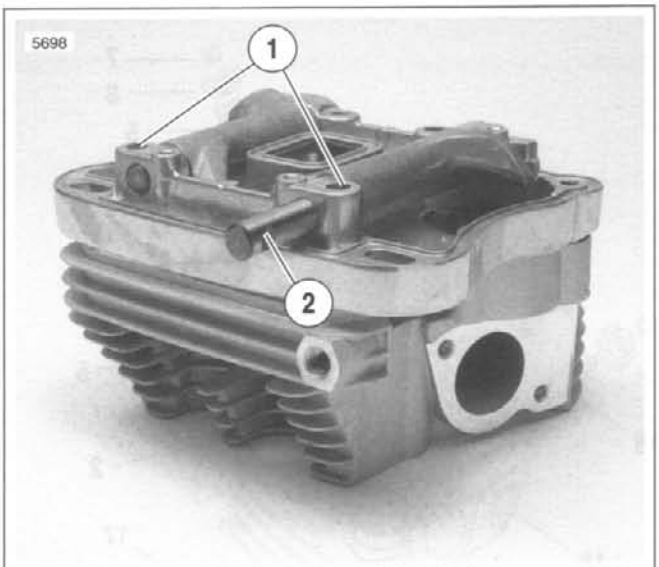
Mark rocker arm shafts for reassembly in their original positions. Valve train components must be reinstalled in their original positions to prevent accelerated wear and increased valve train noise.

8. See Figure 3-7. Remove rocker arm shafts by tapping them out using a hammer and a soft metal punch.
9. See Figure 3-6. Remove rocker arms (10, 11); mark them for reassembly in their original locations.



1. **Screws with washers (4)**
2. **Fiber seal (4)**
3. **Umbrella valve (2)**
4. **Upper rocker cover**
5. **Middle rocker cover**
6. **Gasket**
7. **Gasket**
8. **Gasket**
9. **Rocker arm shafts**
10. **Rocker arm**
11. **Rocker arm**
12. **Bolt and washer (2) (long)**
13. **Bolt and washer (2) (short)**
14. **Screw and washer (2)**
15. **Bolt and washer (3)**
16. **Gasket**
17. **Gasket**
18. **Lower rocker cover**
19. **Rocker arm bushing (8)**

Figure 3-6. Rocker Arm Cover



1. Position of rocker arm retaining bolts
2. Retaining notch

Figure 3-7. Removing Rocker Arm Shafts

CAUTION

Distortion to the head, cylinder and crankcase studs may result if head screws are not loosened (or tightened) gradually in the sequence shown in Figure 3-8.

10. See Figure 3-8. Loosen each head screw 1/8-turn following the sequence shown.

CAUTION

See Figure 3-9. Do not attempt to remove the front isolator mount from front cylinder head. Isolator mount is an integral component and is not meant to be removed unless absolutely necessary. Repeated removals and installations will damage cylinder head threads.

11. Support motorcycle under front header mount. Do not allow engine to drop when performing the next steps.
12. Remove nut, washer and bolt to detach front upper tie bar from isolator and frame.
13. Continue loosening in 1/8-turn increments until screws are loose. Remove head screws.
14. See Figure 3-10. Remove cylinder head (18), head gasket (4), and O-rings (14).

NOTE

Front cylinder head must be removed through upper triangular frame members with front isolator mount attached.

15. Remove both push rod covers and valve tappets. See 3.15 VALVE TAPPETS (1999 models) or 3.16 HYDRAULIC LIFTERS (2000 models).
16. Repeat the above procedure for the other cylinder head.

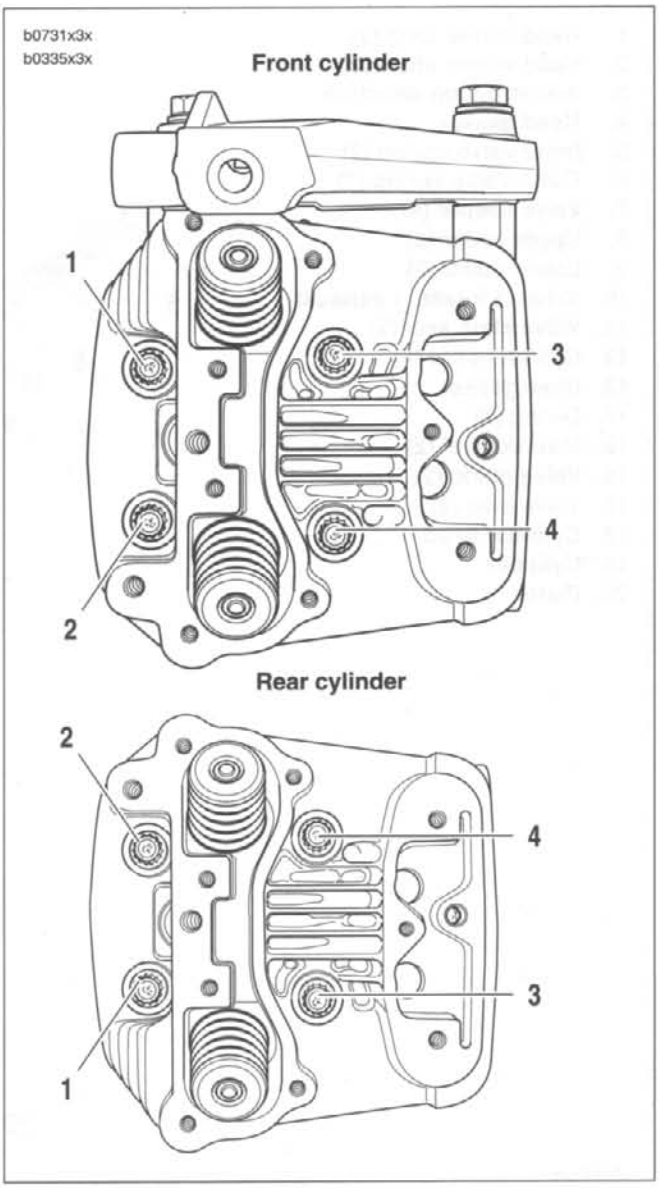


Figure 3-8. Head Screw Loosening/Tightening Sequence

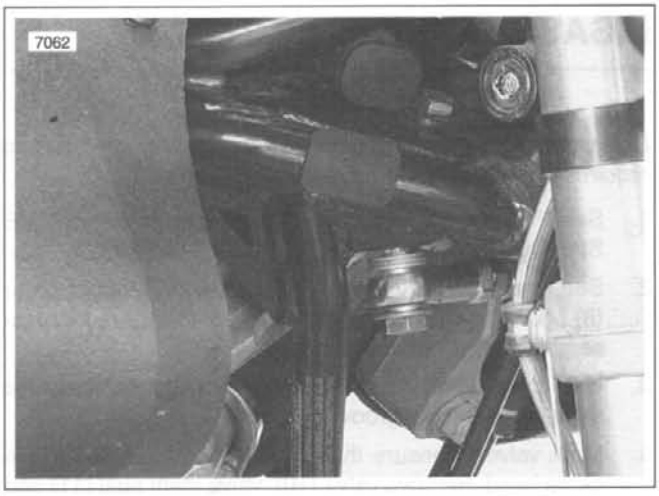
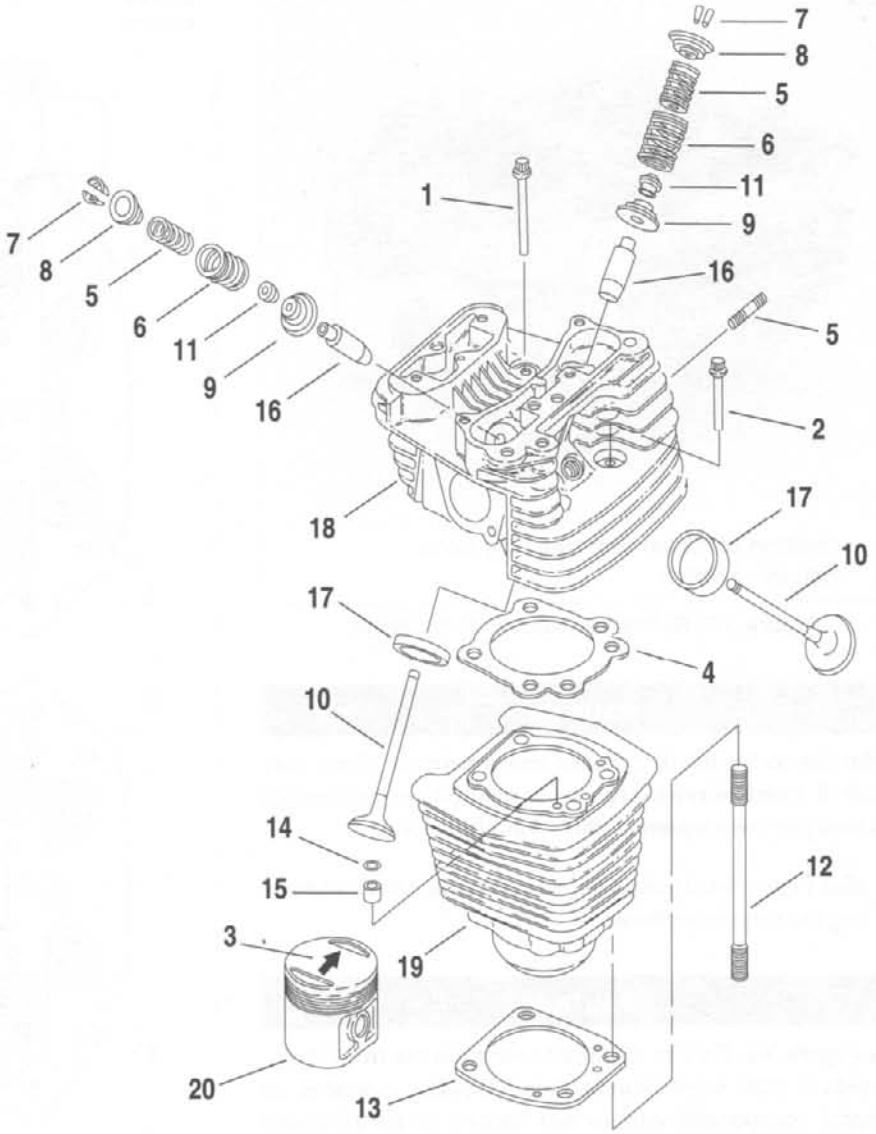


Figure 3-9. Front Isolator Mount and Tie Bar

1. Head screw, long (2)
2. Head screw, short (2)
3. Arrow, piston direction
4. Head gasket
5. Inner valve spring (2)
6. Outer valve spring (2)
7. Valve keeper (4)
8. Upper collar (2)
9. Lower collar (2)
10. Valve (1 intake, 1 exhaust)
11. Valve stem seal (2)
12. Cylinder stud (4)
13. Base gasket
14. O-ring (2)
15. Insert/dowel (2)
16. Valve guide (2)
17. Valve seat (2)
18. Cylinder head
19. Cylinder
20. Piston



xlhcylhead

Figure 3-10. Cylinder Head, Cylinder and Piston

DISASSEMBLY

NOTE

Disassembly of front cylinder exhaust valve components requires front isolator mount removal.

1. See Figure 3-11. Compress valve springs with VALVE SPRING COMPRESSOR (Part No. HD-34736B).
2. See Figure 3-10. Remove valve keepers (7), upper collar (8) and valve springs (5, 6). Mark valve keepers for reassembly in their original locations.
3. Use a fine tooth file to remove any burrs on the valve stem at the keeper groove.
4. Mark valve to ensure that it will be reassembled in the same head. Remove valve (10), valve stem seal (11) and lower collar (9).
5. Repeat the above procedure for the other valve.
6. Disassemble the other head using the same procedure.

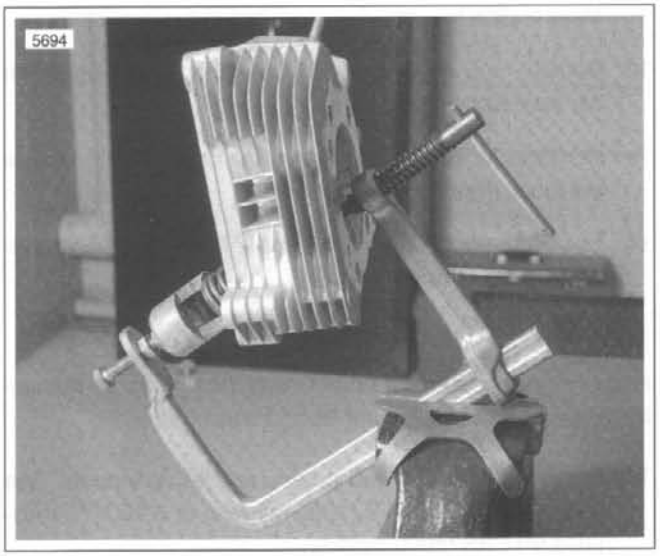


Figure 3-11. Valve Spring Compressor (Part No. HD-34736B)

CLEANING, INSPECTION AND REPAIR

1. Bead blast or scrape carbon from head, top of cylinder and valve ports. Be careful to avoid scratching or nicking cylinder head and cylinder joint faces. Blow off loosened carbon or dirt with compressed air.
2. Soak cylinder head in an aluminum-compatible cleaner/ solvent to loosen carbon deposits.
3. Wash all parts in non-flammable solvent, followed by a thorough washing with hot, soapy water. Blow out oil passages in head. Be sure they are free of sludge and carbon particles. Remove loosened carbon from valve head and stem using a wire wheel. Never use a file or other hardened tool which could scratch or nick valve. Polish valve stem with very fine emery cloth or steel wool.
4. Check each rocker arm, at pad end and push rod end, for uneven wear or pitting. Replace rocker arm if either condition exists.

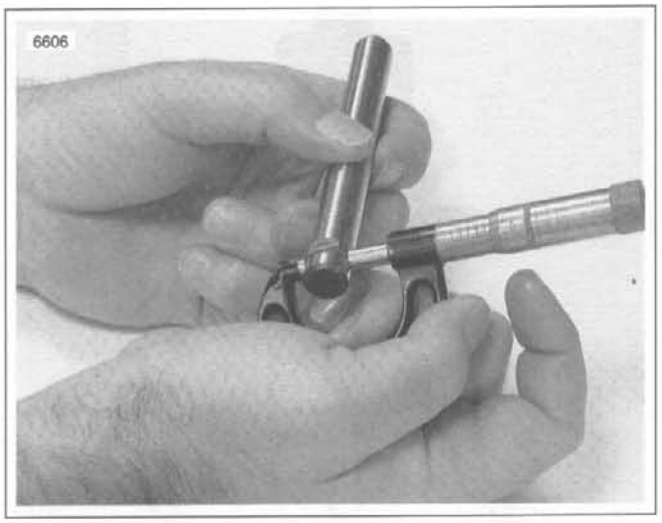


Figure 3-12. Measuring Rocker Arm Shaft Diameter (Rocker Cover Position)

5. Measure and record rocker arm shaft diameter.
   a. See Figure 3-12. Measure where shaft fits in lower rocker arm cover.
   b. See Figure 3-13. Measure where rocker arm bushings ride.
6. Measure and record rocker arm shaft bore diameter.
   a. See Figure 3-14. Measure bore of lower rocker cover.
   b. See Figure 3-15. Measure rocker arm bushing inner diameter.
7. Check the measurements obtained in Steps 5-6 against the SERVICE WEAR LIMITS. Repair or replace parts exceeding limits.
8. Assemble rocker arms and rocker arm shafts into lower rocker cover.
9. Check end play of rocker arm with feeler gauge.
10. Replace rocker arm or lower cover or both if end play exceeds 0.025 in. (0.635 mm).

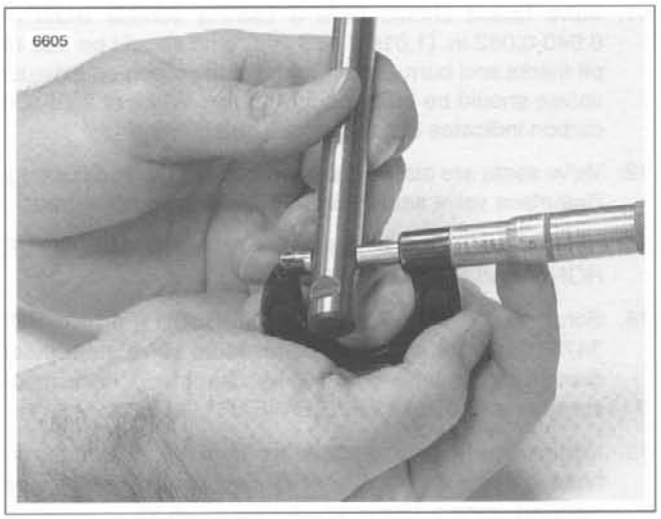


Figure 3-13. Measuring Rocker Arm Shaft Diameter (Rocker Arm Bushing Position)

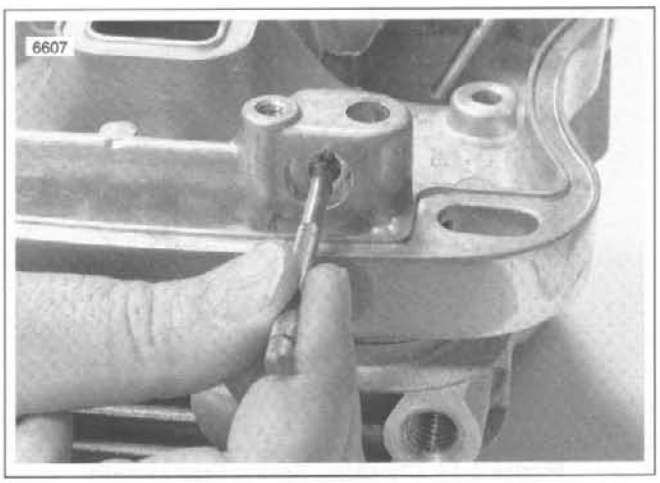


Figure 3-14. Measuring Rocker Arm Shaft Bore Diameter in Lower Rocker Cover

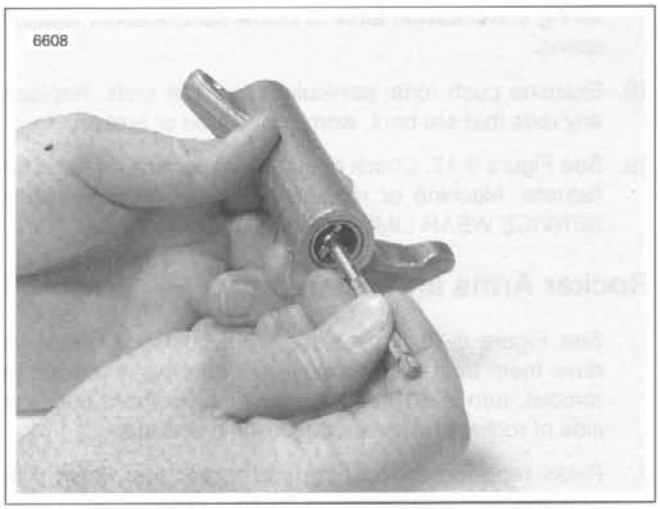


Figure 3-15. Measuring Rocker Arm Bushing Inner Diameter

11. Valve heads should have a seating surface width of 0.040-0.062 in. (1.016-1.575 mm), and should be free of pit marks and burn spots. The color of carbon on exhaust valves should be black or dark brown. White or light buff carbon indicates excessive heat and burning.
12. Valve seats are also subject to wear, pitting, and burning. Resurface valve seats whenever valves are refinished.
13. Clean valve guides by lightly honing with VALVE GUIDE HONE (Part No. HD-34723).
14. Scrub guides with VALVE GUIDE BRUSH (Part No. HD-34751) and hot soapy water. Measure valve stem outer diameter and valve guide inner diameter. Check measurements against SERVICE WEAR LIMITS.
15. Inspect spark plug threads for damage. If threads in head are damaged, a special plug type insert can be installed using a 12 mm spark plug repair kit.
16. Inspect valve springs for broken or discolored coils.

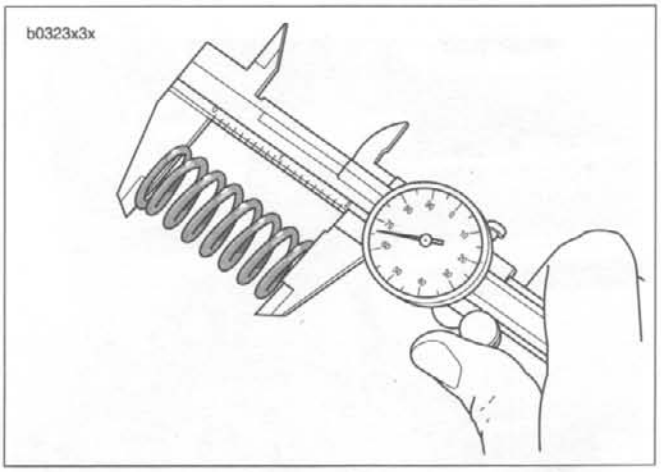


Figure 3-16. Checking Spring Free Length

17. See Figure 3-16. Check free length and compression force of each spring. Compare with SERVICE WEAR LIMITS. If spring length is shorter than specification or if spring compression force is below specification, replace spring.
18. Examine push rods, particularly the ball ends. Replace any rods that are bent, worn, discolored or broken.
19. See Figure 3-17. Check head gasket surface on head for flatness. Machine or replace any head which exceeds SERVICE WEAR LIMIT of 0.006 in. (0.152 mm).

Rocker Arms and Bushings

1. See Figure 3-18. To replace worn bushings, press or drive them from the rocker arm. If bushing is difficult to remove, turn a 9/16-18 tap into bushing. From opposite side of rocker arm, press out bushing and tap.
2. Press replacement bushing into rocker arm, flush with arm end, and split portion of bushing towards top of arm.
3. Using remaining old bushing as a pilot, line ream new bushing with ROCKER ARM BUSHING REAMER (Part No. HD-94804-57).
4. Repeat for other end of rocker arm.

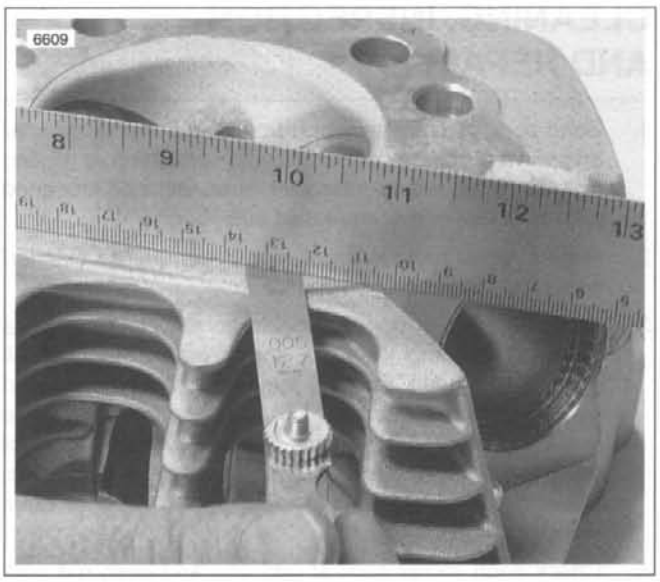


Figure 3-17. Checking Gasket Surface

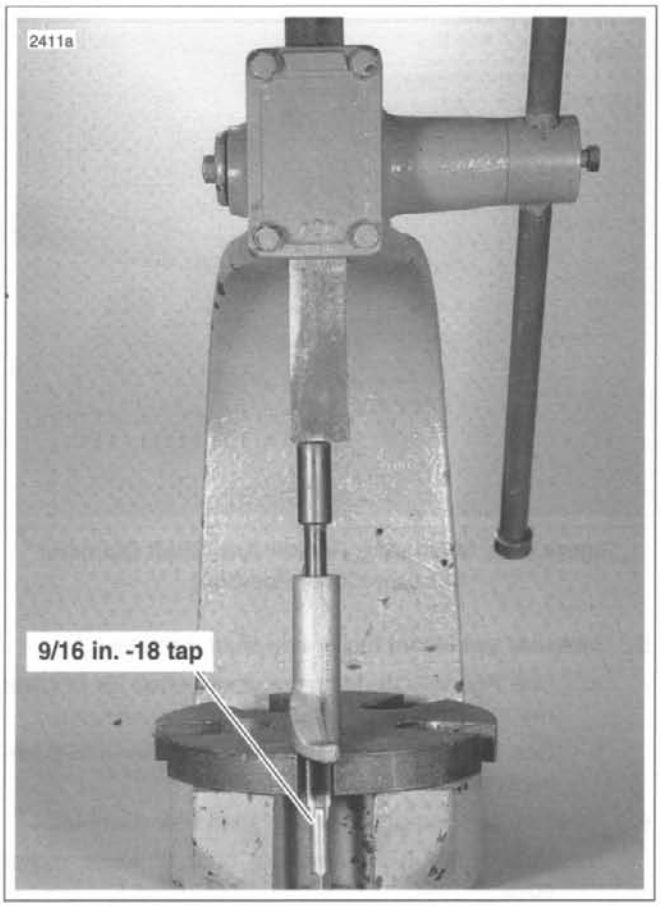


Figure 3-18. Removing Rocker Arm Bushing

Replacing Valve Guides

Valve guide replacement, if necessary, must be done before valve seat is ground. It is the valve stem hole in valve guide that determines seat grinding location. Valve stem-to-valve guide clearances are listed in Table 3-3. If valve stems and/or guides are worn beyond limits, install **new** parts.

Table 3-3. Valve Stem Clearances and Service Wear Limits

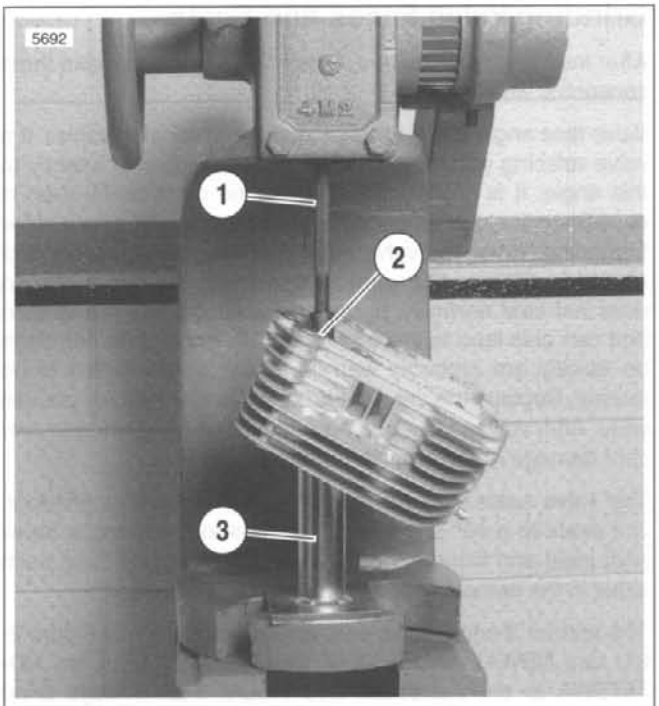
VALVE	CLEARANCE	SERVICE WEAR LIMIT
Exhaust	0.0015-0.0033 in. (0.0381-0.0838 mm)	0.0040 in. (0.1016 mm)
Intake	0.008-0.0026 in. (0.203-0.0660 mm)	0.0035 in. (0.0889 mm)

1. To remove shoulderless guides, press or tap guides toward combustion chamber using DRIVER HANDLE AND REMOVER (Part No. HD-34740).
2. Clean and measure valve guide bore in head.
3. Measure outer diameter of a new standard valve guide. The guide diameter should be 0.0020-0.0033 in. (0.0508-0.0838 mm). larger than bore in head. If it is not, select one of the following oversizes: +0.001 in. (+0.025 mm), +0.002 in. (+0.051 mm) or +0.003 in. (+0.076 mm) (intake and exhaust).
4. See Figure 3-19. Install shoulderless guides using VALVE GUIDE INSTALLATION TOOL (2) (Part No. HD-34731) and DRIVER HANDLE (1) (Part No. HD-34740). Press or drive guide until the tool touches the machined surface surrounding the guide. At this point, the correct guide height has been reached.
5. Ream guides to final size or within 0.0010 in. (0.0254 mm) of final size using VALVE GUIDE REAMER (Steel, Part No. HD-39932 or Carbide, Part No. HD-39932-CAR). Use REAMER LUBRICANT (Part No. HD-39964) or liberal amounts of suitable cutting oil to prevent reamer chatter.
6. Apply the proper surface finish to the valve guide bores using the VALVE GUIDE HONE (Part No. HD-34723). Lubricate hone with honing oil. Driving hone with an electric drill, work for a crosshatch pattern with an angle of approximately 60°.

NOTE

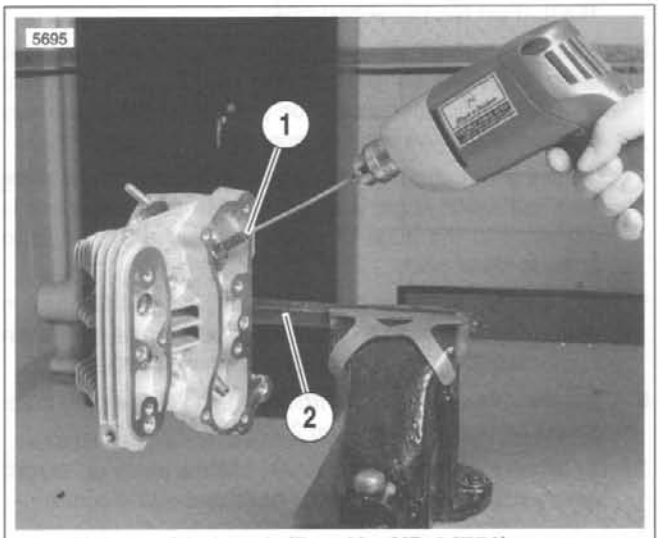
The hone is not intended to remove material.

7. See Figure 3-20. Thoroughly clean valve guide bores using VALVE GUIDE BRUSH (1) (Part No. HD-34751) and hot soapy water.



1. **Driver handle (Part No. HD-34740)**
2. **Valve guide installation tool (Part No. HD-34731)**
3. **Cylinder head stand (Part No. HD-39782)**

Figure 3-19. Installing Shoulderless Valve Guide



1. **Valve guide brush (Part No. HD-34751)**
2. **Cylinder head holding fixture (Part No. HD-39786)**

Figure 3-20. Cleaning Valve Guides

Grinding Valve Faces and Seats

After installing valve guides, reface valve seats to make them concentric with guides.

Valve face angle is 45° for both intake and exhaust valves. If a valve refacing grinder is used, it must be adjusted exactly to this angle. It is important to remove no more metal than is necessary to clean up and true valve face. Install a **new** valve if grinding leaves the valve edge (the margin) with a width of less than 1/32 in. (0.8 mm). A valve with too thin a margin does not seat normally, burns easily, may cause pre-ignition and can also lead to valve cracking. Valves that do not clean up quickly are probably warped or too deeply pitted to be reused. Replace the valve if end of valve stem shows uneven wear. After valves have been ground, handle with care to prevent damage to the ground faces.

The valve seats may be refinished with cutters or grinders. Cut seats to a 46° angle or grind seats to a 45° angle. Valve seat tools and fixtures are available commercially. Seat each valve in the same position from which it was removed.

The correct 3-angle valve seat angles are shown in Figure 3-21. Use NEWAY VALVE SEAT CUTTER SET (Part No. HD-35758A) to cut the seats. See Figure 3-22. Always grind valves before cutting seats.

1. Cut 46° (or grind 45°) valve seat angle first. Use cutting oil to avoid chatter marks. Cut or grind only enough to clean up the seat.
2. Apply a small amount of lapping compound to the valve face. Rotate valve against seat using VALVE LAPPING TOOL (Part No. HD-96550-36A).
3. See Figure 3-21. Check the contact pattern on valve face. It should be 0.040-0.062 in. (1.016-1.575 mm) wide, and its center should be positioned 2/3 of the way toward the outside edge of face.
4. If valve seat pattern is too close to the stem side of valve face, cut a 60° angle in order to raise seat. If pattern is too close to the edge of valve face, cut a 31° angle in order to lower seat.
5. After cutting either or both 31° or 60° angles to position seat, final cut 46° (or grind 45°) seat angle to obtain proper 0.040-0.062 in. (1.016-1.575 mm) width.
6. Recheck valve seat width and location with lapping compound as described in Step 2.
7. To achieve a smooth even finish, place a piece of 280 grit emery paper under the cutter head and rotate cutter.

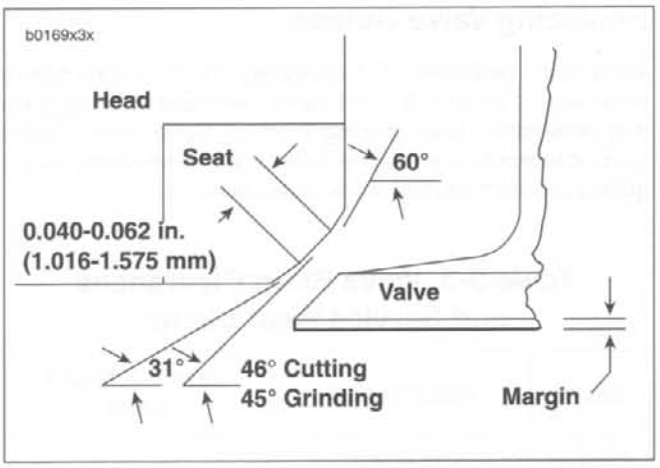


Figure 3-21. Valve Seat Angles

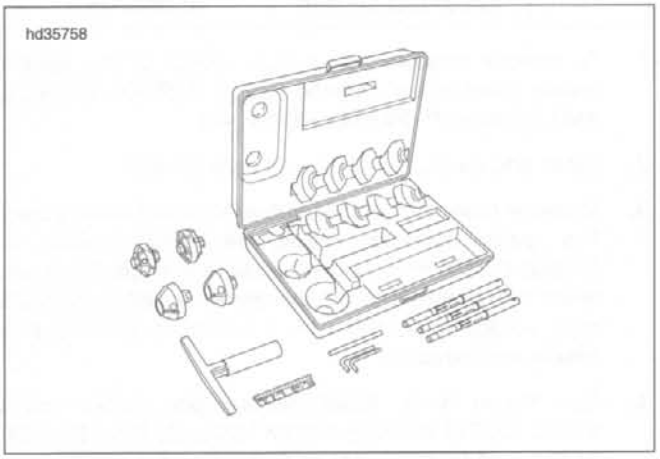


Figure 3-22. Valve Seat Cutter

Table 3-4. Neway Valve Seat Cutters

VALVE SEAT	60° CUTTER	31° AND 46° CUTTERS
Exhaust	Part No. 205	Part No. 622
Intake	Part No. 293	Part No. 642

CAUTION

Do not grind valve to shorten. Grinding will remove the case hardening and expose the stem's mild steel core resulting in rapid end wear.

8. See Figure 3-23. Wipe valve seats and valve faces clean. Measure valve stem protrusion.
   a. If valve stem protrudes more than 2.031 in. (51.587 mm), replace valve seat or cylinder head.
   b. If valve stem protrusion is acceptable, valves and seats are ready for lapping.

Replacing Valve Seats

Replacing a valve seat is a complex operation requiring special equipment. If the seat is loose or is not fully seated in the head, then seat movement will prevent the proper transfer of heat from the valve. The seat surface must be flush with (or below) the head surface. See 3.1 SPECIFICATIONS for valve seat-to-cylinder head fit.

To remove the old seat, lay a bead of weld material around the inside diameter of the seat. This will shrink the seat outside diameter and provide a surface for driving the seat out the port side.

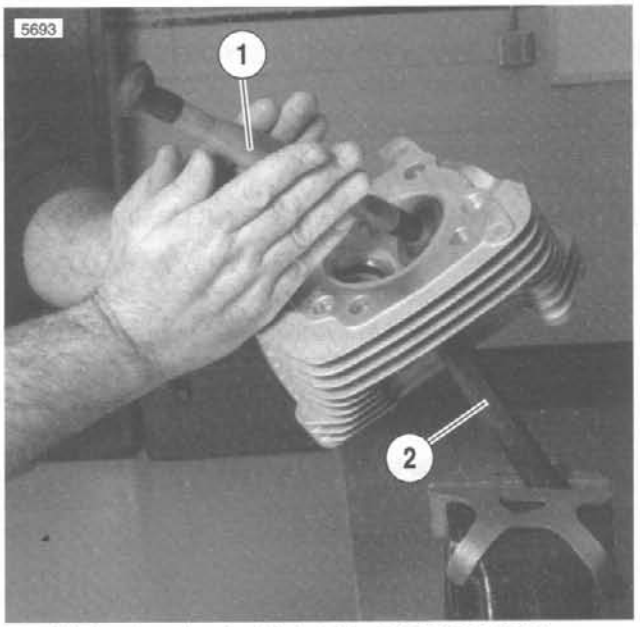
Lapping Valve Faces and Seats

NOTE

If valve faces and seats have been smoothly and accurately refaced, very little lapping will be required to complete the seating operation.

1. See Figure 3-24. Use CYLINDER HEAD HOLDING FIXTURE (2) (Part No. HD-39786) to secure cylinder head.
   a. Apply a light coat of fine lapping compound to valve face. Insert valve in guide.
   b. Place one rubber cup end of VALVE LAPPING TOOL (1) (Part No. HD-96550-36A) onto head of valve.
   c. Holding lapping tool as shown, apply only very light pressure against valve head.
   d. Rotate lapping tool and valve alternately clockwise and counterclockwise a few times.
2. Lift valve and rotate it about 1/3 of a turn clockwise. Repeat lapping procedure in Step 1.
3. Repeat Step 2. Then, remove valve.
4. Wash valve face and seat. Dry parts with a **new**, clean cloth or towel.
5. Inspect valve and seat.
   a. If inspection shows an unbroken lapped finish of uniform width around both valve and seat, valve is well seated.
   b. If lapped finish is not complete, further lapping (or grinding and lapping) is necessary.

Figure 3-23. Measuring Valve Stem Protrusion



1. **Valve lapping tool (Part No. HD-96550-36A)**
2. **Cylinder head holding fixture (Part No. HD-39786)**

Figure 3-24. Lapping Valves

ASSEMBLY

CAUTION

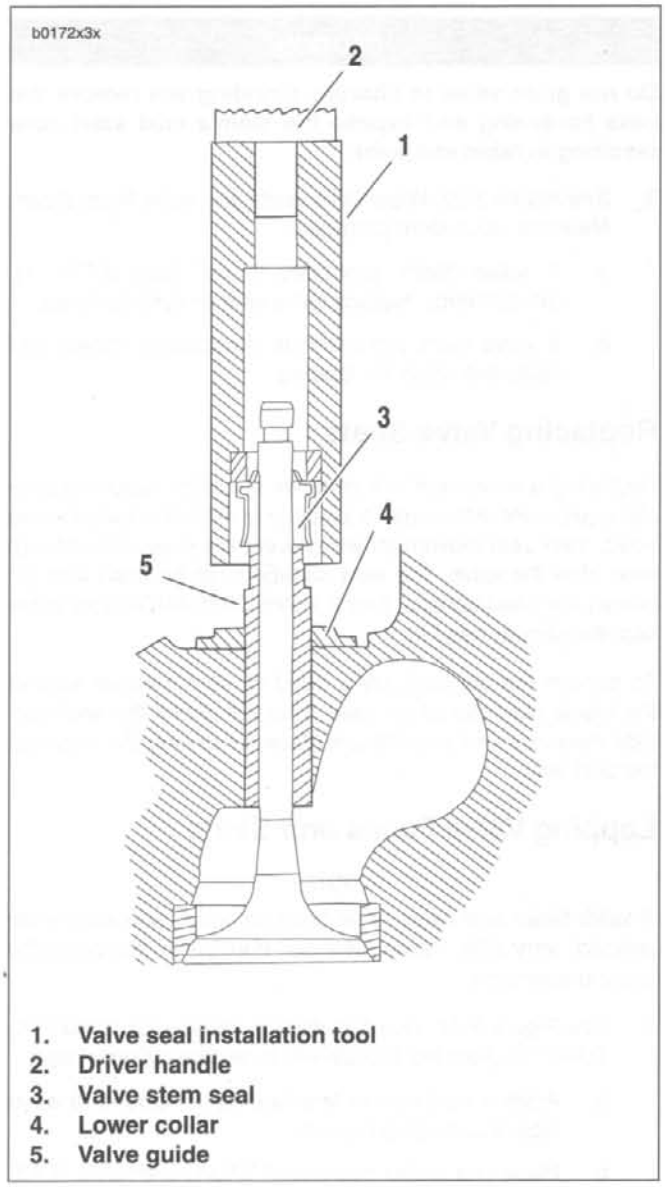
Make sure all lapping compound is removed from cylinder head and valves after lapping is completed. If lapping compound contaminates any internal engine components or engine oil, excessive engine wear and damage may result.

1. Wash cylinder head and valves in warm, soapy water to remove all lapping compound.
2. Scrub valve guide bores with VALVE GUIDE BRUSH (Part No. HD-34751) and hot, soapy water.
3. Blow dry with compressed air.
4. Apply a liberal amount of engine oil to the valve stem.
5. See Figure 3-25. Insert valve into valve guide (5) and install lower collar (4).
6. See Figure 3-26. Place a protective sleeve over the valve stem keeper groove. Coat the sleeve with oil and place a **new** seal over the valve stem.

CAUTION

- **Always use a protective sleeve on the valve stem keeper groove when installing valve stem seal. If the seal is installed without using the protective sleeve, the seal will be damaged.**
- **Do not remove valve after seal is installed. Otherwise, sharp edges on keeper groove will damage seal.**

7. See Figure 3-25. Tap the valve stem seal (3) onto the valve guide (5) using the VALVE SEAL INSTALLATION TOOL (Part No. HD-34643A) and DRIVER HANDLE (Part No. HD-34740). The seal is completely installed when the tool touches the lower collar (4).
8. See Figure 3-10. Install valve springs (5, 6) and upper collar (8).
9. Compress springs with VALVE SPRING COMPRESSOR (Part No. HD-34736B).
10. Insert valve keepers (7) into upper collar (8), making sure they engage groove in valve stem. The keeper gaps should be equal.
11. Release and remove VALVE SPRING COMPRESSOR.
12. Repeat Steps 4-11 for the remaining valve(s).
13. If front isolator mount was removed, install as follows.
    a. Chase threads in cylinder head with a 7/16-14 TPI NC tap before installing **new** bolts.
    b. Coat **new** bolts with LOCTITE THREADLOCKER 262 (red).
    c. Tighten bolts to 73-78 ft-lbs (98.9-105.7 Nm).



1. **Valve seal installation tool**
2. **Driver handle**
3. **Valve stem seal**
4. **Lower collar**
5. **Valve guide**

Figure 3-25. Valve Seal Installation

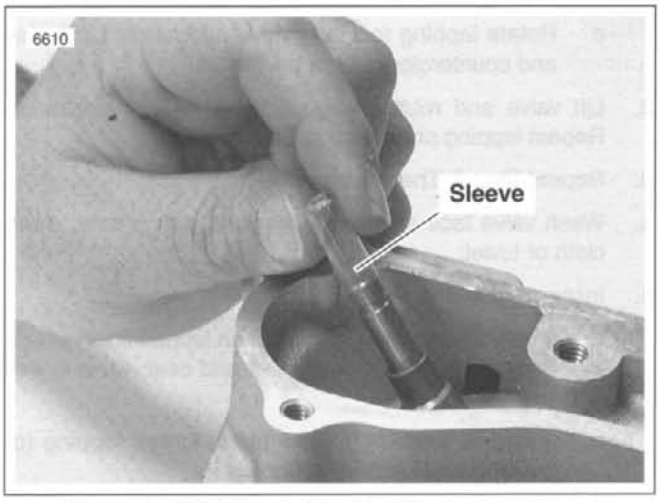


Figure 3-26. Valve Guide Seal Protector Sleeve

INSTALLATION

If only cylinder head work was needed, reinstall cylinder head following these instructions. If further repair is required, see 3.6 CYLINDER AND PISTON.

1. See Figure 3-10. Coat mating surfaces of cylinder studs (12) and head screws (1, 2) with parts cleaning solution.
2. Scrape old oil and any carbon deposits from threads by using a back-and-forth motion, threading each head screw onto its mating cylinder stud.
3. Remove head screws from studs. Wipe or blow dry thread surfaces.
4. Apply oil to stud threads and to the underside of the head screw shoulder.

CAUTION

Only oil film must remain on the head screw surfaces. Too much oil will pool in the head screw sleeve. Pooled oil may prevent proper torque application and full thread engagement.

5. Blow or wipe off excess oil from head screws.
6. Thoroughly clean and dry the gasket surfaces of cylinder (19) and cylinder head (18).
7. Install a **new** O-ring (14) on each dowel (15).

NOTE

O-rings (14) help to properly position the head gasket (4). O-rings must be installed before the head gasket.

8. Install a **new** head gasket (4) to cylinder.
9. Carefully lower cylinder head over studs and position on dowels. Use great care so as not to disturb head gasket.

CAUTION

The procedure for tightening the head screws is critical to proper distribution of pressure over gasket area. It prevents gasket leaks, stud failure, and head and cylinder distortion.

10. See Figure 3-8. For each cylinder head, start with screw numbered one, as shown. In increasing numerical sequence (i.e. – 1, 2, 3 and 4):
    a. Tighten each screw to 7-9 ft-lbs (9.5-12.2 Nm).
    b. Tighten each screw to 13-15 ft-lbs (17.6-20.3 Nm).
    c. Loosen all screws.
11. After screws are loosened from initial torque, tighten head screws in three stages. Tighten fasteners in increasing numerical sequence (i.e. – 1, 2, 3 and 4).
    a. Tighten each screw to 7-9 ft-lbs (9.5-12.2 Nm).
    b. Tighten each screw to 13-15 ft-lbs (17.6-20.3 Nm).
    c. See Figure 3-27. Mark cylinder head and head screw shoulder with a line as shown (View A). Tighten each screw a 1/4-turn (90°) (View B).

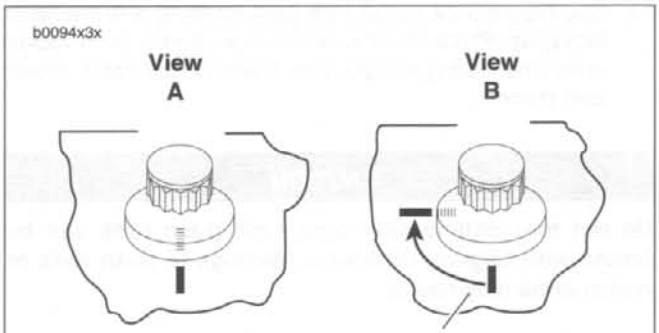
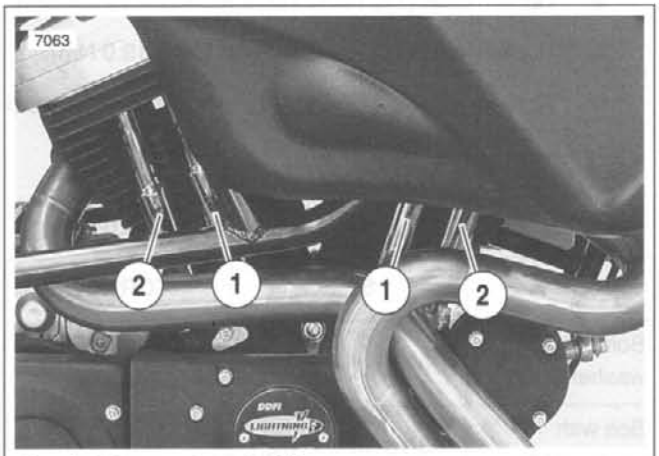


Figure 3-27. Tightening Head Screws



1. **Intake push rods (2)**
2. **Exhaust push rods (2)**

Figure 3-28. Push Rod Locations (Shown on Assembled Engine)

Table 3-5. Push Rod Selection

POSITION	COLOR CODE	LENGTH	PART NUMBER
Exhaust (front & rear)	3 Band-Pink	10.800 in. (274.320 mm)	17904-89
Intake (front & rear)	1 Band-Brown	10.746 in. (272.948 mm)	17897-89

12. Install tappets and push rod covers. See 3.15 VALVE TAPPETS (1999 models) or 3.16 HYDRAULIC LIFTERS (2000 models).
13. See Figure 3-28. Identify push rod color coding, length and respective push rod positions in engine. See Table 3-5. Place intake and exhaust push rods onto seat at top of tappet.

14. See Figure 3-29. Install **new** gaskets (8, 9) with the bead facing up. Place lower rocker box assembly (with rocker arms and shafts) into position. Place push rods in rocker arm sockets.

CAUTION

Do not turn engine over until both push rods can be turned with fingers. Otherwise, damage to push rods or rocker arms may result.

15. See Figure 3-30. Install fasteners (12, 13, 14 and 15). Slowly snug all fasteners in small increments (one turn at a time). Use a cross pattern on the four large bolts (12, 13) that fasten the lower rocker box to head. This will bleed the tappets. Fastener sizes are listed in Table 3-6.

    a. Tighten bolts (12, 13) to 15-19 ft-lbs (20.3-25.8 Nm).

    b. Tighten bolts (15) to 10-14 ft-lbs (13.6-19.0 Nm).

    c. Tighten screws (14) to 130-150 **in-lbs** (13.6-19.0 Nm).

Table 3-6. Lower Rocker Box Hardware

ITEM	SIZE	TORQUE
Bolt with washer (12)	5/16-18 X 2-3/4	15-19 ft-lbs (20.3-25.8 Nm)
Bolt with washer (13)	5/16-18 X 2-1/2	
Screw with washer (14)	1/4-20 X 1-1/2	130-150 **in-lbs** (14.7-16.9 Nm)
Bolt with washer (15)	1/4-20 X 1-1/4	10-14 ft-lbs (13.6-19.0 Nm)

NOTES

Tubular frame prohibits direct access to bolt (12) on right rear cylinder. Use TORQUE ADAPTOR (SNAP-ON Part No. FRDH 181) and TORQUE COMPUTER (SNAP-ON Part No. SS-306G) to correctly assemble.

16. See Figure 3-29. Install middle and upper rocker covers.

    a. Place a **new** gasket (7) on lower rocker box assembly.

    b. Install middle rocker cover (5) with umbrella valve next to intake manifold.

    c. Place a **new** gasket (6) on middle rocker cover.

    d. Install upper rocker cover (4) using screws with washers (1) and **new** fiber seals (2). Tighten screws to 10-14 ft-lbs (13.6-19.0 Nm).

17. Install the other cylinder using the same procedure.

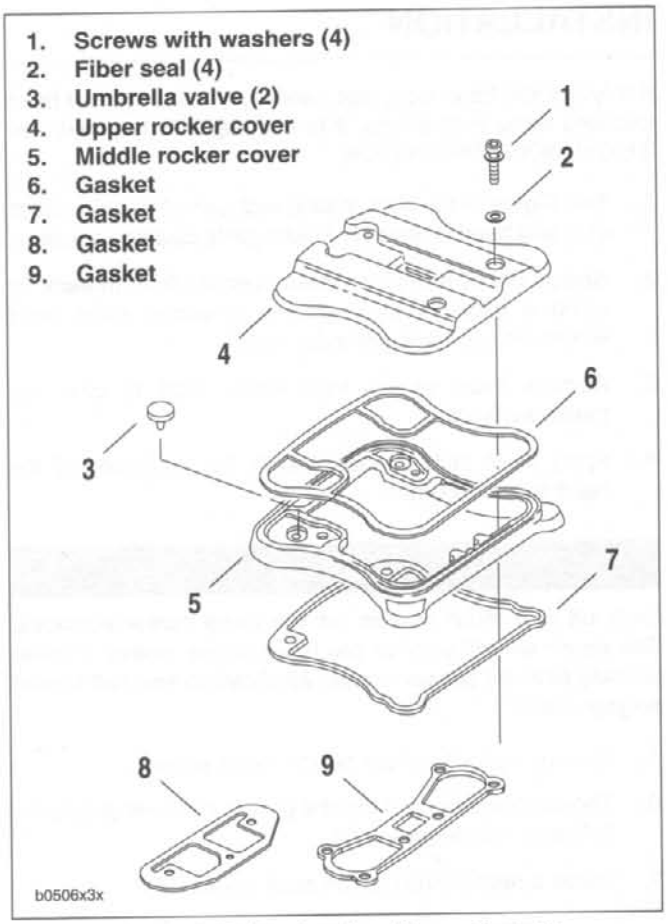


Figure 3-29. Rocker Arm Cover Gaskets

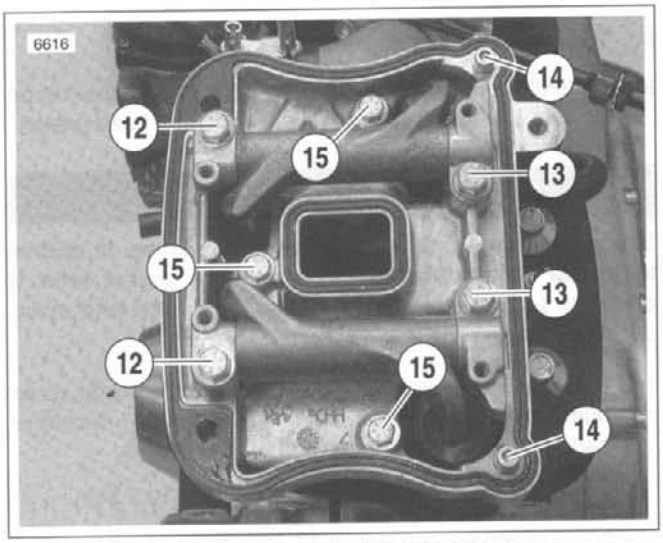


Figure 3-30. Lower Rocker Box Fasteners (Same Numbers as Figure 3-6.)

REMOVAL/DISASSEMBLY

1. Strip motorcycle as described under DISASSEMBLING ENGINE FOR CYLINDER HEAD REPAIR.
2. Remove cylinder head. See 3.5 CYLINDER HEAD.
3. Clean crankcase around cylinder base to prevent dirt and debris from entering crankcase while removing cylinder.
4. See Figure 3-31. Turn engine over until piston (3) of cylinder being removed is at bottom of its stroke.
5. Carefully raise cylinder (1) just enough to permit placing clean towel under piston to prevent any foreign matter from falling into crankcase.

NOTE

If cylinder does not come loose, lightly tap a plastic hammer perpendicular to the cylinder fins. Never try to pry a cylinder up.

6. Carefully lift cylinder over piston and cylinder studs (4). Do not allow piston to fall against cylinder studs. Discard cylinder base gasket (5).

CAUTION

With cylinder removed, be careful not to bend the cylinder studs. The slightest bend could cause a stress riser and lead to stud failure.

7. Install a 6.0 in. (152 mm) length of 1/2 in. (12.7 mm) ID plastic or rubber hose over each cylinder stud. This will protect the studs and the pistons.

⚠WARNING

Always wear proper eye protecton when removing the compression rings. Slippage may propel the ring with enough force to cause an accident. This could result in death or serious injury.

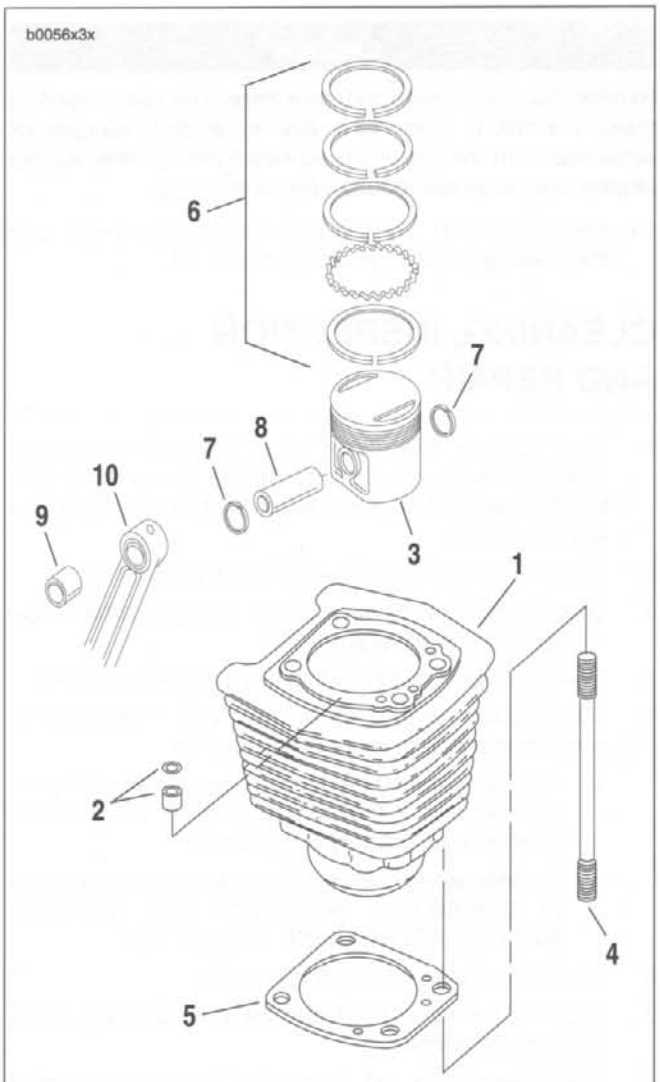
CAUTION

The piston pin retaining rings must not be reused. Removal may weaken retaining rings and they may break or dislodge. Either occurrence may damage engine.

8. Insert an awl in the recessed area below the piston pin bore and pry out the piston pin retaining rings. To prevent the ring from flying out, place your thumb over the retaining ring.

NOTE

Since the piston pin is a loose fit in the piston, the pin will easily slide out. The pins have tapered ends to help seat the round retaining rings. See Figure 3-32. 1200cc piston pins are stamped with a V-groove at one end.



1. **Cylinder**
2. **Dowel (2) and O-ring (2)**
3. **Piston**
4. **Cylinder stud (4)**
5. **Base gasket**
6. **Ring set**
7. **Retaining ring (2)**
8. **Piston pin**
9. **Piston pin bushing**
10. **Connecting rod**

Figure 3-31. Cylinder and Piston

9. Mark each pin boss with either an "F" or an "R" to indicate front or rear cylinder, respectively. See Figure 3-32. The arrow at the top of 1200cc pistons must always point toward the front of the engine.

CAUTION

Handle the piston with extreme care. The alloy used in these pistons is very hard. Any scratches, gouges or other marks in the piston could score the cylinder during engine operation and cause engine damage.

10. See Figure 3-31. Spread piston rings (6) outward until they clear grooves in piston (3) and lift off.

CLEANING, INSPECTION AND REPAIR

1. Soak cylinder and piston in an aluminum-compatible cleaner/solvent until deposits are soft, then clean with a brush. Blow off loosened carbon and dirt particles and wash in solvent.
2. Clean oil passage in cylinder with compressed air.
3. Clean piston ring grooves with a piece of compression ring ground to a chisel shape.
4. Examine piston pin to see that it is not pitted or scored.
5. Check piston pin bushing to see that it is not loose in connecting rod, grooved, pitted or scored.
   a. A piston pin properly fitted to upper connecting rod bushing has a 0.00125 to 0.00175 in. (0.03175-0.04445 mm) clearance in bushing.
   b. If piston pin-to-bushing clearance exceeds 0.00200 in. (0.05080 mm), replace worn parts. See CONNECTING ROD BUSHING on page 3-28.
6. Clean piston pin retaining ring grooves.
7. Examine piston and cylinder for cracks, burnt spots, grooves and gouges.
8. Check connecting rod for up and down play in lower bearings. When up and down play is detected, lower bearing should be refitted. This requires removing and disassembling engine crankcase.

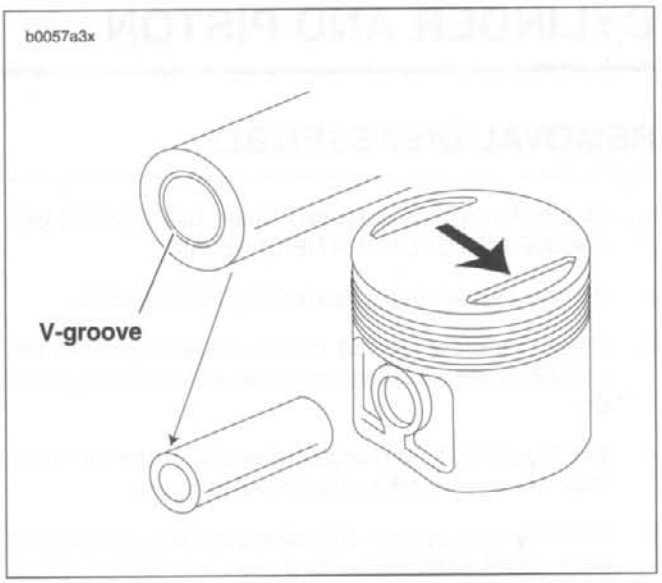


Figure 3-32. Piston Pin and Piston Identification

Checking Gasket Surface

CAUTION

If either cylinder gasket surface does not meet flatness specifications, replace cylinder and piston. Proper tolerances will extend component life and prevent leaks.

1. See Figure 3-33. Check cylinder head gasket surface for flatness.
   a. Lay a straightedge across the surface.
   b. Try to insert a feeler gauge between the straightedge and the gasket surface.
   c. If cylinder head gasket surface is not flat within 0.006 in. (0.152 mm), replace cylinder and piston.
2. Check cylinder base gasket surface for flatness.
   a. Lay a straightedge across the surface.
   b. Try to insert a feeler gauge between the straightedge and the gasket surface.
   c. If cylinder base gasket surface is not flat within 0.008 in. (0.203 mm), replace cylinder and piston.

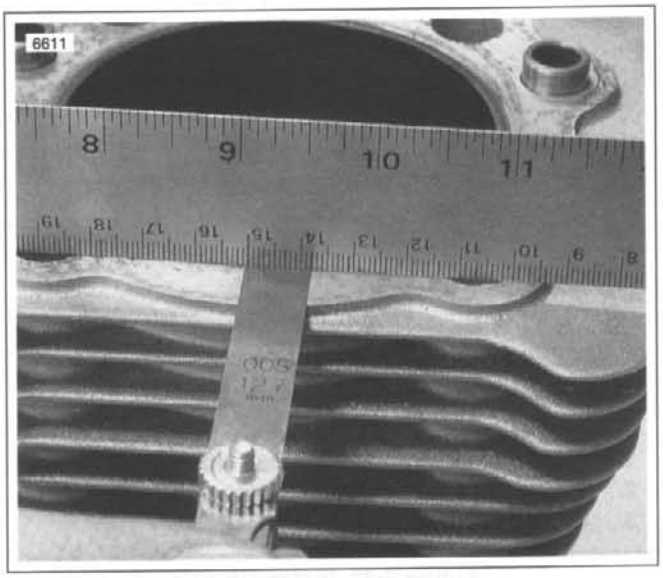


Figure 3-33. Checking Gasket Surfaces

Measuring Cylinder Bore

1. Remove any burrs from the cylinder gasket surfaces.
2. See Figure 3-34. Install a head and base gasket, and CYLINDER TORQUE PLATES (Part No. HD-33446A) and XL EVOLUTION TORQUE PLATE BOLTS (Part No. HD-33446-86). Tighten the bolts using the same method used when installing the cylinder head screws. See 3.5 CYLINDER HEAD.

NOTE

Torque plates, properly tightened and installed with gaskets, simulate engine operating conditions. Measurements will vary as much as 0.001 in. (0.025 mm) without torque plates.

3. Take cylinder bore measurement in ring path, starting about 1/2 in. (12.7 mm) from top of cylinder, measuring from front to rear and then side to side. Record readings.
4. Repeat measurement at center and then at bottom of ring path. Record readings. This process will determine if cylinder is out-of-round (or "egged") and will also show any cylinder taper or bulge.
5. See Table 3-7. If cylinder is not scuffed or scored and is within service limit, see 3.6 CYLINDER AND PISTON on page 3-26.

NOTE

If piston clearance exceeds service limit, cylinders should be rebored and/or honed to next standard oversize, and refitted with the corresponding piston and rings. Do not fit piston tighter than 0.0007 in. (0.0178 mm). See 3.1 SPECIFICATIONS.

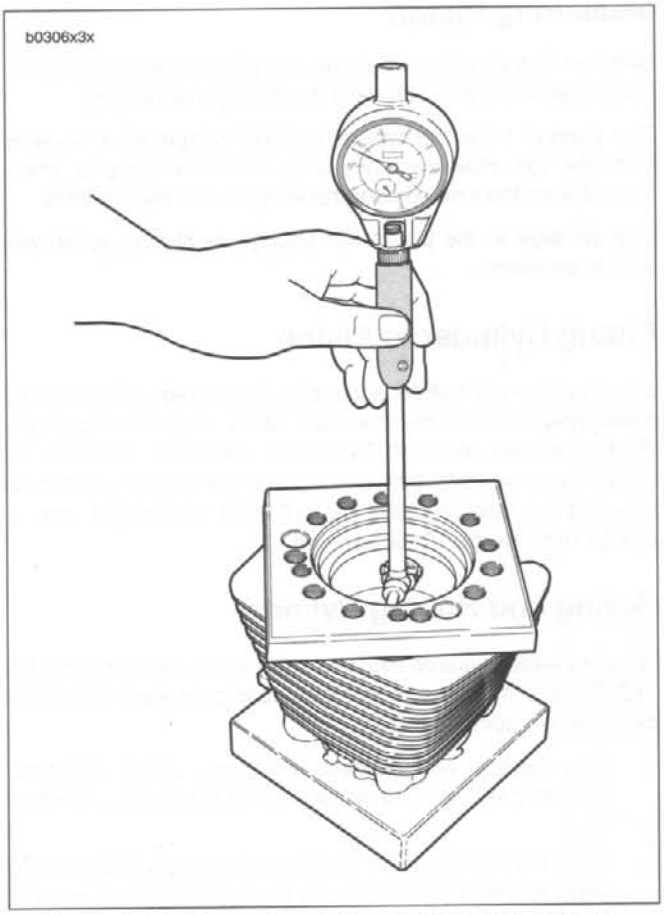


Figure 3-34. Measuring Cylinder Bore Using Torque Plates (Part No. HD-33446A)

Table 3-7. 1200cc Cylinder Bore Service Wear Limits

BORE SIZES	IN.	MM
Standard Bore	3.5008	88.9203
0.005 in. OS bore (0.127 mm)	3.5050	89.0270
0.010 in. OS bore (0.254 mm)	3.5100	89.1540
0.020 in. OS bore (0.508 mm)	3.5200	89.4080
0.030 in. OS bore (0.762 mm)	3.5300	89.6620

Measuring Piston

Because of their complex shape, the pistons cannot be accurately measured with standard measuring instruments.

The pistons have the typical elliptical shape when viewed from the top. However, they also are barrel-shaped when viewed from the side. This barrel shape is not symmetrical.

Any damage to the piston will change its shape, which will lead to problems.

Fitting Cylinder to Piston

Since pistons cannot be accurately measured with standard measuring instruments, the bore sizes must be observed. Bore sizes are listed in Table 3-8. Example: A 0.005 in. (0.127 mm) oversize piston will have the proper clearance with a bore size of 3.502 in. ± 0.0002 in. (88.951 mm ± 0.0051 mm) for the 1200cc engine.

Boring and Honing Cylinder

When cylinder requires oversize reboring to beyond 0.030 in. (0.762 mm), the oversize limit has been exceeded and cylinder must be replaced.

1. Bore cylinder with gaskets and torque plates attached. Bore to 0.003 in. (0.076 mm) under the desired finished size.
2. Hone the cylinder to its finished size using a 280 grit rigid hone followed by a 240 grit flexible ball hone. Honing must be done with the torque plates attached. All honing must be done from the bottom (crankcase) end of the cylinder. Work for a 60° crosshatch pattern.

Fitting Piston Rings

NOTE

Ring sets and pistons, 0.040 in. (1.016 mm) oversize, are not available on 1200cc engines.

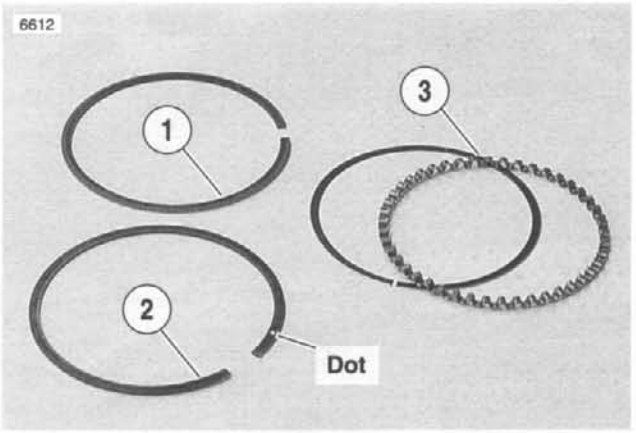
See Figure 3-35. Piston rings are of two types: compression (1, 2) and oil control (3). The two compression rings are positioned in the two upper piston ring grooves. The dot on the second compression ring must face upward. Ring sets are available to fit standard and oversize pistons.

Piston ring sets must be properly fitted to piston and cylinder:

1. See Figure 3-36. Place piston in cylinder about 1/2 in. (12.7 mm) from top. Set ring to be checked squarely against piston as shown. Check end gap with thickness gauge. See 3.1 SPECIFICATIONS for tolerance.

NOTE

See SERVICE WEAR LIMITS for end gap dimensions. Do not file rings to obtain proper gap.



1. **Top compression ring – Install either side up**
2. **Second compression ring – Install dot toward top**
3. **Oil control rings**

Figure 3-35. Piston Rings

Table 3-8. Final Cylinder Bore Sizes

BORE SIZES	IN.	MM
Standard bore*	3.4978 in.	88.8441 mm
0.005 in. OS bore (0.127 mm)	3.502 in.	88.951 mm
0.010 in. OS bore (0.254 mm)	3.507 in.	89.078 mm
0.020 in. OS bore (0.508 mm)	3.517 in.	89.332 mm
0.030 in. OS bore (0.762 mm)	3.527 in.	89.586 mm

*All bore sizes + 0.0002 in. (0.0051 mm)

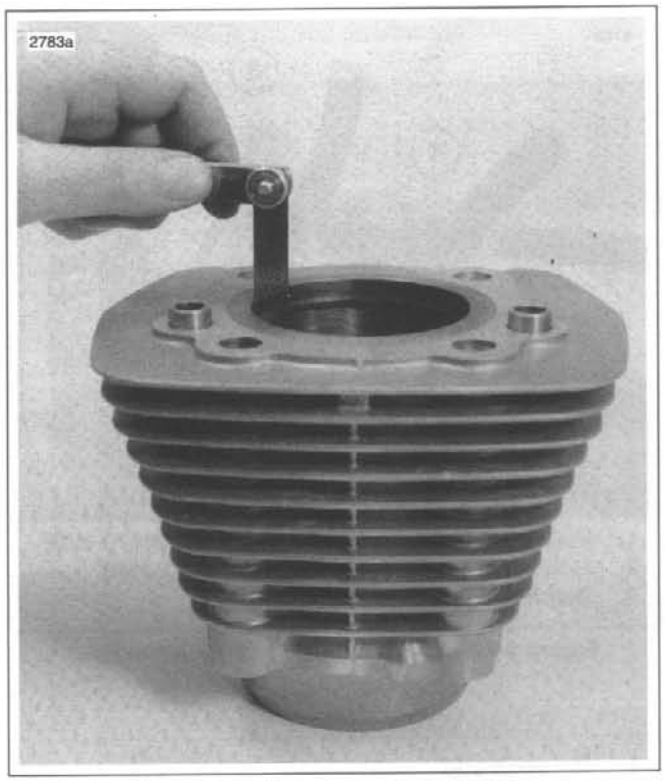


Figure 3-36. Measuring Ring End Gap

NOTE

The same piston may be used if cylinder bore was not changed, unless it is scuffed or grooved. However, replace rings and hone the cylinder walls with a No. 240 grit flexible hone to facilitate ring seating.

2. See Figure 3-37. Apply engine oil to piston grooves. Use TRANSMISSION SHAFT RETAINING RING PLIERS (Part No. J-5586) to slip compression rings over piston into their respective grooves. Be extremely careful not to over expand, twist rings or damage piston surface when installing rings.

NOTE

Install second compression ring with dot towards top.

3. See Figure 3-38. Install rings so end gaps of adjacent rings are a minimum of 90° apart. Ring gaps are not to be within 10° of the thrust face centerline.
4. See Figure 3-39. Check for proper side clearance with thickness gauge, as shown. See 3.1 SPECIFICATIONS for tolerance.

NOTE

If the ring grooves are clean and the side play is still not correct, replace the rings, the piston or both.

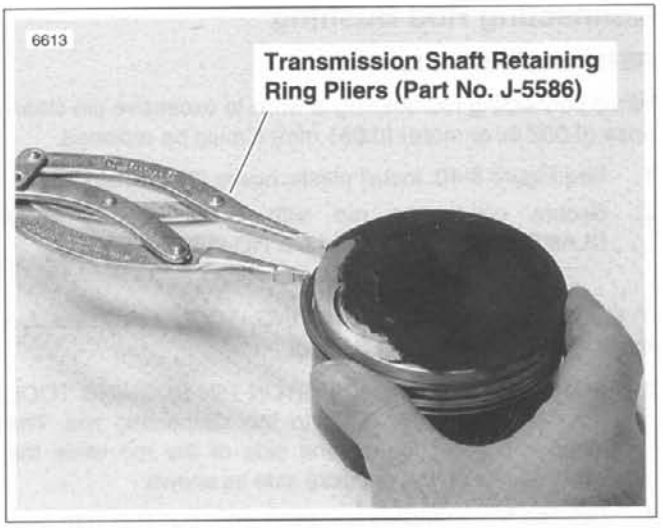


Figure 3-37. Installing Piston Rings

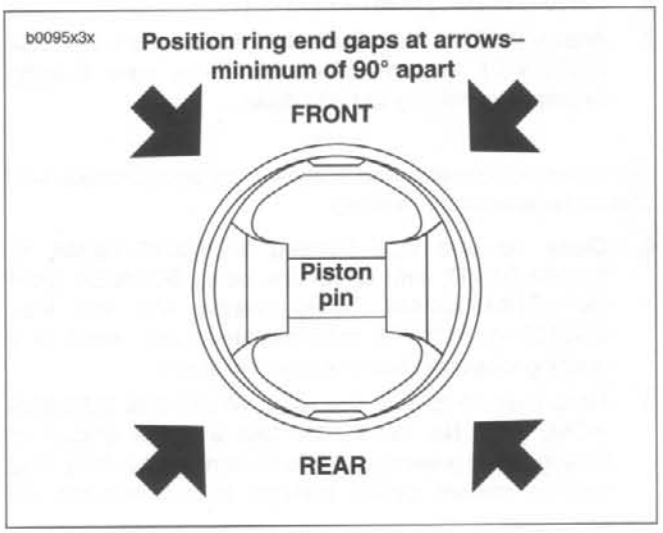


Figure 3-38. Ring End Gap Position

Figure 3-39. Measuring Ring Clearance in Groove

Connecting Rod Bushing

REMOVAL/INSTALLATION

When connecting rod bushing is worn to excessive pin clearance (0.002 in. or more) (0.051 mm) it must be replaced.

1. See Figure 3-40. Install plastic hoses (3) over studs.
2. Secure connecting rod with CONNECTING ROD CLAMPING TOOL (2) (Part No. HD-95952-33B).

NOTE

If CONNECTING ROD CLAMPING TOOL holes are too small, enlarge the holes in the tool.

3. See Figure 3-41. Attach PISTON PIN BUSHING TOOL (Part No. HD-95970-32D) to the connecting rod. The receiver cup (1) fits on one side of the rod while the driver (2) fits on the opposite side as shown.
4. Use two box wrenches and push worn bushing from connecting rod.
5. Remove piston pin bushing tool from connecting rod.
6. Remove bushing from receiver cup.
7. Attach PISTON PIN BUSHING TOOL (Part No. HD-95970-32D) to connecting rod. Place **new** bushing between connecting rod and driver.

NOTE

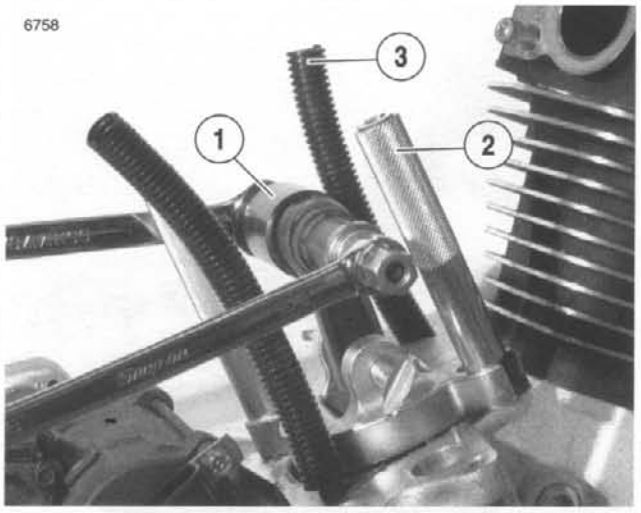
The driver must be attached facing the opposite direction as it was for removal of the bushing.

8. Clean up and size bushing to 0.0010-0.0005 in. (0.0254-0.0127 mm) undersize using REAMER (Part No. HD-94800-26A). Sizing bushing with less than 0.00125 in. (0.03175 mm) clearance can result in a bushing loosening and/or seized pin in rod.
9. Hone bushing to final size using WRIST PIN BUSHING HONE (Part No. HD-35102). Use a liberal amount of honing oil to prevent damage to hone or bushing. Use care to prevent foreign material from falling into the crankcase.

REPAIR

CAUTION

Replace bent connecting rods. Do not attempt to straighten. Straightening rods by bending will damage the bearing on the crank pin and the piston pin bushing. Installing bent connecting rods will damage cylinder and piston beyond repair.



1. **Piston pin bushing tool (Part No. HD-95970-32D)**
2. **Rod clamping tool (Part No. HD-95952-33B)**
3. **Plastic hose**

Figure 3-40. Installing New Piston Pin Bushing

1. **Receiver cup**
2. **Driver**
3. **Washer**
4. **Nut**
5. **Bolt**
6. **Bearing**

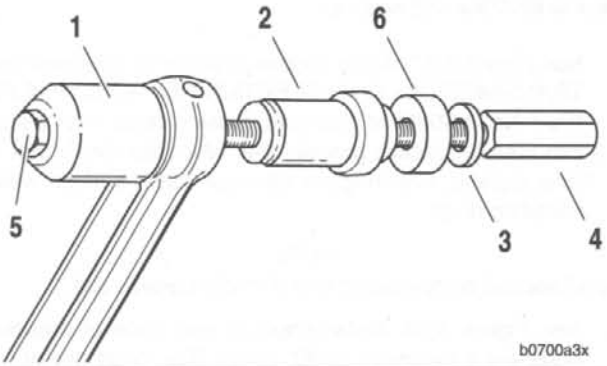


Figure 3-41. Piston Pin Bushing Tool Assembly for Bushing Removal

ASSEMBLY/INSTALLATION

1. See Figure 3-42. Place PISTON SUPPORT PLATE (3) (Part No. HD-42322) around connecting rod.
2. Install piston assembly over connecting rod.

NOTE

New 1200cc pistons must be installed with the arrow, at the top of the piston, pointing towards the front of the engine.

3. Install piston pin.

CAUTION

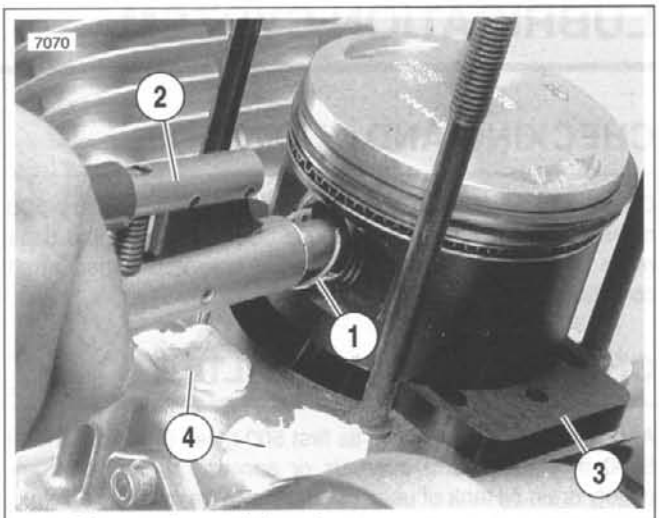
Always use new retaining ring. Make sure retaining ring groove is clean and that ring seats firmly in groove. If it does not, discard the ring. Never install a used retaining ring or a new one if it has been installed and then removed for any reason. A loosely installed ring will come out of the piston groove and damage cylinder and piston beyond repair.

4. Install **new** piston pin retaining rings (1) using PISTON PIN RETAINING RING INSTALLER (2) (Part No. HD-34623B). Place **new** retaining ring on tool with gap pointing up. See Figure 3-43.

NOTE

Make sure the ring groove is clean. Ring must be fully seated in the groove with the gap away from the slot at the bottom.

5. See Figure 3-38. Make sure the piston ring end gaps are properly positioned as shown.
6. Remove PISTON SUPPORT PLATE.
7. Lubricate cylinder wall, piston, pin and rod bushing with engine oil.
8. Turn engine until piston is at top dead center.
9. See Figure 3-44. Compress the piston rings using PISTON RING COMPRESSOR (Part No. HD-96333-51C).
10. Remove protective sleeves from cylinder studs. Install a **new** cylinder base gasket. Make sure the piston does not bump the studs or crankcase.
11. Install cylinder over piston.
12. Remove PISTON RING COMPRESSOR.
13. Assemble cylinder head. See 3.5 CYLINDER HEAD.
14. Install cylinder head. See 3.5 CYLINDER HEAD.
15. Install assembled engine. See 3.4 INSTALLING THE ENGINE.



1. **Piston pin retaining ring**
2. **Piston pin retaining ring installer**
3. **Piston support plate**
4. **Plugged tappet holes**

Figure 3-42. Installing Piston Retaining Rings

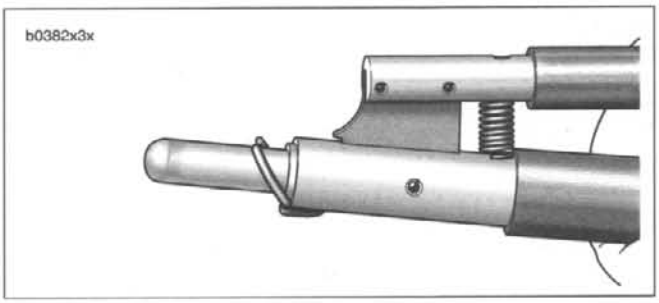
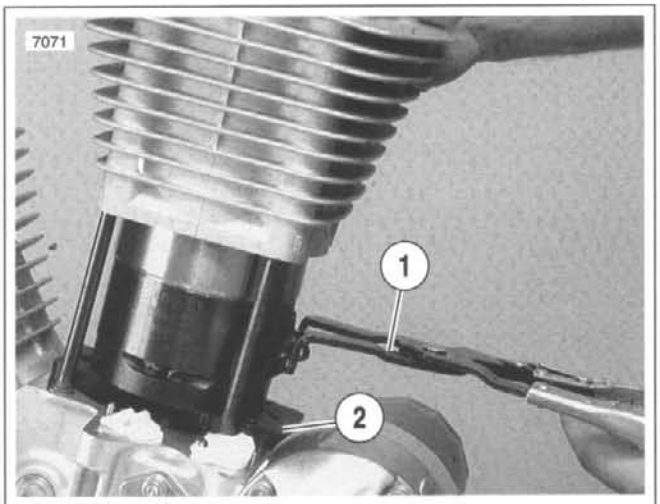


Figure 3-43. Aligning Retaining Ring



1. **Piston ring compressor**
2. **Piston support plate**

Figure 3-44. Compressing Piston Rings

CHECKING AND ADDING OIL

Check engine oil level in oil tank at least once every 500 miles (800 km). Check level more frequently if engine uses more oil than normal or if vehicle is operated under harsh conditions.

CHANGING OIL AND FILTER

After a new engine has run its first 500 miles (800 km) and at 5000 mile (8000 km) intervals or annually thereafter, completely drain oil tank of used oil. Refill with fresh oil. If vehicle is driven extremely hard, used in competition or driven on dusty roads, change engine oil at shorter intervals. Always change oil filter when changing engine oil.

NOTE

See 1.6 ENGINE LUBRICATION SYSTEM for more information on checking oil level and changing oil and filter.

WINTER LUBRICATION

Normal fuel combustion in a gasoline engine produces water vapor and carbon dioxide along with other gases and particulates. When first starting and warming an engine, some of the water vapor that gets into the engine crankcase condenses to form liquid water. If the engine is driven long enough to thoroughly warm the crankcase, most of this liquid water is again vaporized and exhausted through the crankcase breather system.

A moderately driven vehicle making short runs may not be able to vacate water vapors allowing liquid water to accumulates in the oil tank. This is especially true if the vehicle is operated in cold weather. In freezing weather, an accumulation of water in the engine oil may become slush or ice, which can block oil lines and lead to severe engine damage. Water remaining in the engine oil for long periods of time can form an acidic sludge that is corrosive to metal engine parts and causes accelerated wear of moving components.

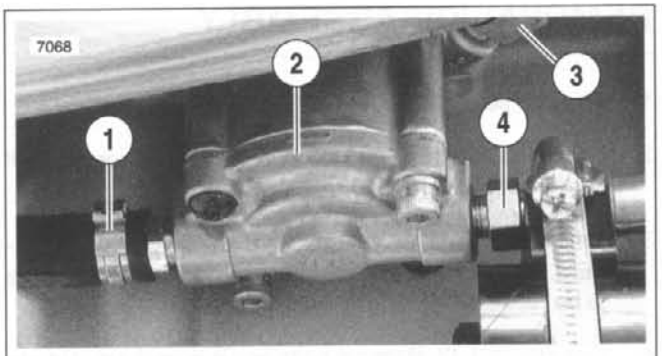
In winter the oil change interval should be shorter than normal. The colder the weather, the shorter the recommended oil change interval. A vehicle used only for short runs in cold weather must have the engine oil drained frequently.

GENERAL

See Figure 3-45. The oil tank has four hoses. The drain hose (2) attaches to a fitting on the left side. From the top of the tank, the vent hose (3) runs along the right side to below the battery tray. The return hose (4) runs along the left side and joins the bottom feed hose (1) under the battery tray.

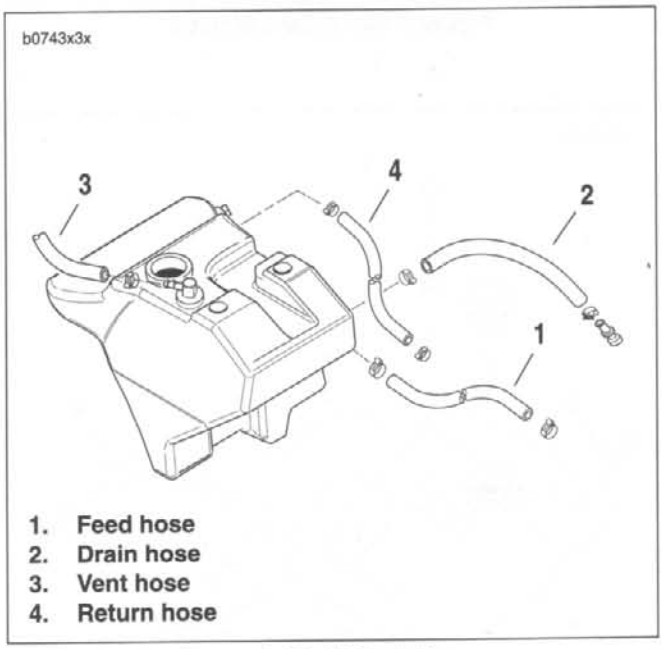
See Figure 3-46. The feed (1) and return hoses (3) run together between the swingarm mount block and crankcase, beneath the engine and forward to the oil pump. The feed hose attaches to the rear most oil pump fitting; the return hose connects forward and above. To prevent unnecessary wear, the hoses have a fitted cover.

After diverging from the feed and return hoses, the vent hose is routed beneath the starter. It continues on to the right side of the motorcycle. See Figure 3-47. Here the vent hose (1) connects to an elbow fitting (3) on the gearcase cover (4).



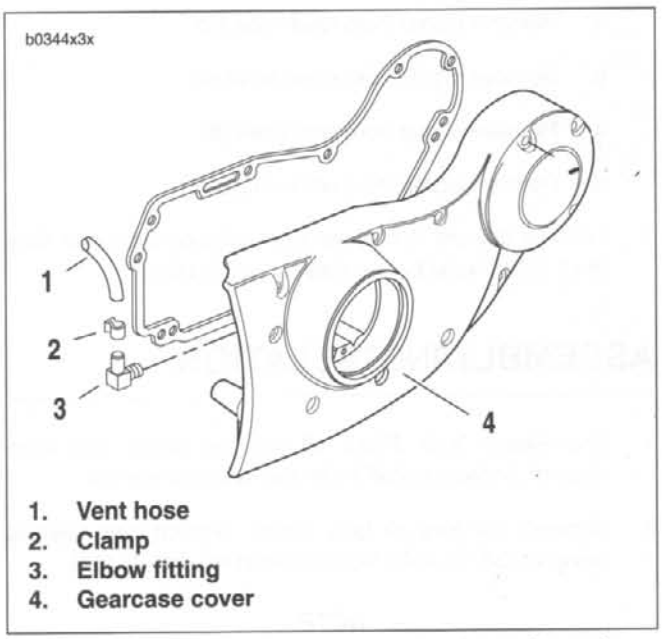
1. Feed hose
2. Oil pump
3. Return hose
4. Oil filter hose connection

Figure 3-46. Oil Pump Connections



1. Feed hose
2. Drain hose
3. Vent hose
4. Return hose

Figure 3-45. Oil Tank Hoses

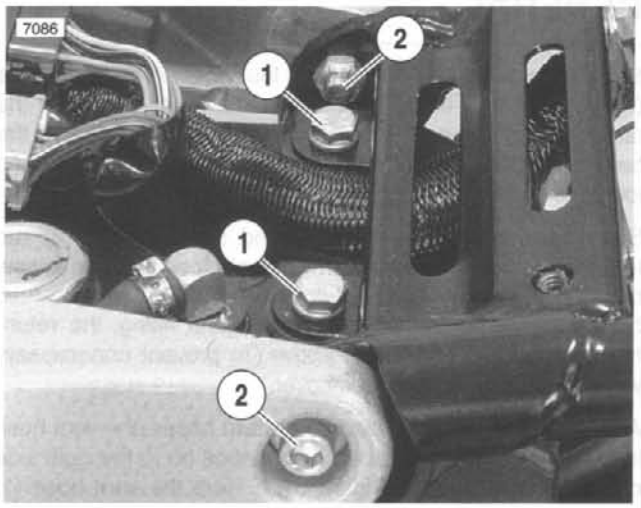


1. Vent hose
2. Clamp
3. Elbow fitting
4. Gearcase cover

Figure 3-47. Vent Hose Connection (1999 Shown)

REMOVAL/DISASSEMBLY

1. Remove seat.
2. Remove lower bolts on tail section and disconnect tail section wiring. See 2.46 TAIL SECTION.
3. Drain oil tank. See 1.6 ENGINE LUBRICATION SYSTEM. The oil filter need not be removed unless it is due to be replaced.
4. See Figure 3-48. Remove bolts and lockwashers (1) from well nuts.
5. Loosen top bolts (2) on tail section. Rotate tail section upward. Secure with straps.
6. See Figure 3-49. Remove clamps to detach hoses from oil tank. Label each hose upon removal.
   a. Remove clamp from feed hose (3).
   b. Remove clamp from drain hose (4).
   c. Remove clamp from vent hose (6).
   d. Remove clamp from return hose (5).
7. Lift tank upward to remove. Both tabs on bottom of tank must clear frame before detaching oil tank.



1. **Bolt and lockwasher (2)**
2. **Top bolts on tail section (2)**

Figure 3-48. Oil Tank Mounts

ASSEMBLY/INSTALLATION

1. See Figure 3-49. Place oil tank on frame and align mounts. Loosely install bolts and lockwashers (1).
2. Connect the four oil tank hoses. Tighten **new** clamps using HOSE CLAMP PLIERS (Part No. HD-41137).

NOTE

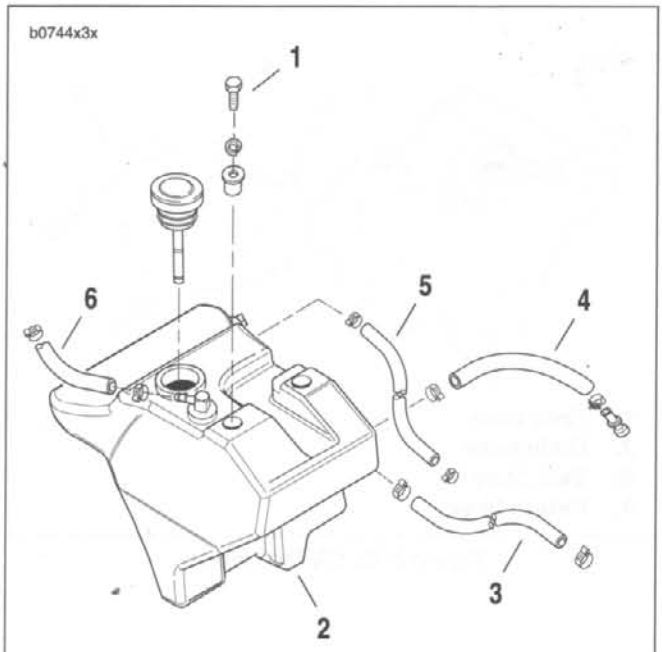
Clamp may be reused on feed hose (3) at oil tank connection.

3. Fill oil tank. See 1.6 ENGINE LUBRICATION SYSTEM.
4. Attach tail section. See 2.46 TAIL SECTION.

⚠WARNING

After installing seat, pull upward on front of seat to be sure it is locked in position. If seat is loose, it could shift during vehicle operation and startle the rider, causing loss of control. These events could result in death or serious injury.

5. Install seat.



1. **Bolt, lockwasher and well nut (4)**
2. **Oil tank**
3. **Feed hose with 3/8 in. clamps**
4. **Drain hose with plug assembly and 3/8 in. clamp**
5. **Return hose with 3/8 in. clamps**
6. **Vent hose with 1/4 in. clamps**

Figure 3-49. Oil Tank

OIL PRESSURE INDICATOR SWITCH 3.10

GENERAL

The oil pressure indicator switch is a pressure-actuated diaphragm-type switch. When oil is not circulating through the system or when oil pressure is abnormally low, spring tension holds the switch contacts closed, thereby completing the signal light circuit and causing the indicator lamp to illuminate.

OIL PRESSURE SIGNAL LIGHT

The oil pressure signal light turns ON when:

- Ignition switch is turned on prior to starting engine.
- Oil is not circulating through the running engine.
- Oil pressure is abnormally low on the running engine.
- Engine is idling far below 1000 RPM.

The oil pressure signal light turns OFF when:

- Oil is circulating with adequate pressure through the engine running at 1000 RPM or greater.

Troubleshooting information is listed in Table 3-9.

NOTE

If the ignition is turned back on immediately after the engine is stopped, the oil light may not turn on right away because of oil pressure retained in the filter housing.

OIL PRESSURE

See Figure 3-50. The oil pump is nonregulatory and delivers its entire volume of oil under pressure to the oil filter mount. When an engine is cold, the engine oil will be more viscous (i.e., thicker). During start-up of a cold engine, oil pressure will be higher than normal and oil circulation will be somewhat restricted within the oiling system. As the engine warms to normal operating temperature, the engine oil will warm up and become less viscous — oil pressure decreases.

When an engine is operated at high speeds, the volume of oil circulated through the oiling system increases, resulting in higher oil pressure. As engine speed is reduced, the volume of oil pumped is also reduced, resulting in lower oil pressure.

To check oil pressure, use OIL PRESSURE GAUGE (Part No. HD-96921-52A) and OIL PRESSURE GAUGE ADAPTER (Part No. HD-96940-52A). Remove oil pressure indicator switch and insert pressure gauge fitting. See Figure 3-51.

Ride motorcycle at least 20 miles (32 km) at or above 50 MPH (80 KM/H) until engine oil reaches normal operating temperature. At 2500 RPM, oil pressure will vary from 10-17 psi (69-117 kN/m^2). At idle speed (950-1050 RPM), oil pressure will vary from 7-12 psi (48-83 kN/m^2).

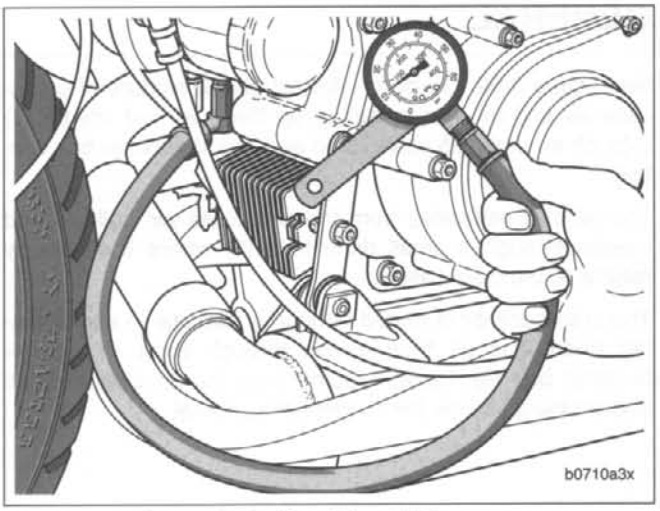


Figure 3-50. Checking Oil Pressure

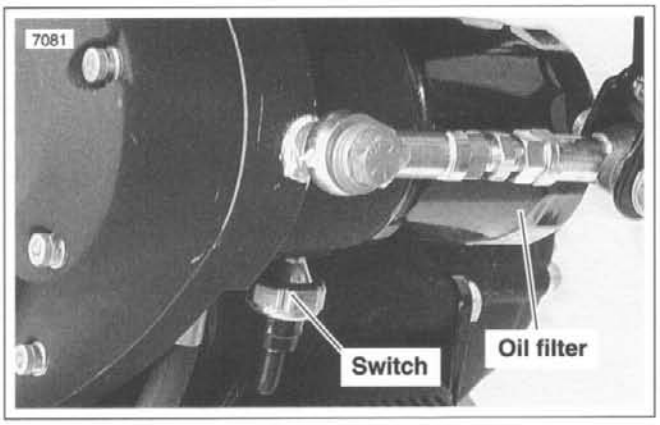


Figure 3-51. Oil Pressure Indicator Switch

Table 3-9. Troubleshooting Oil Pressure Signal Light

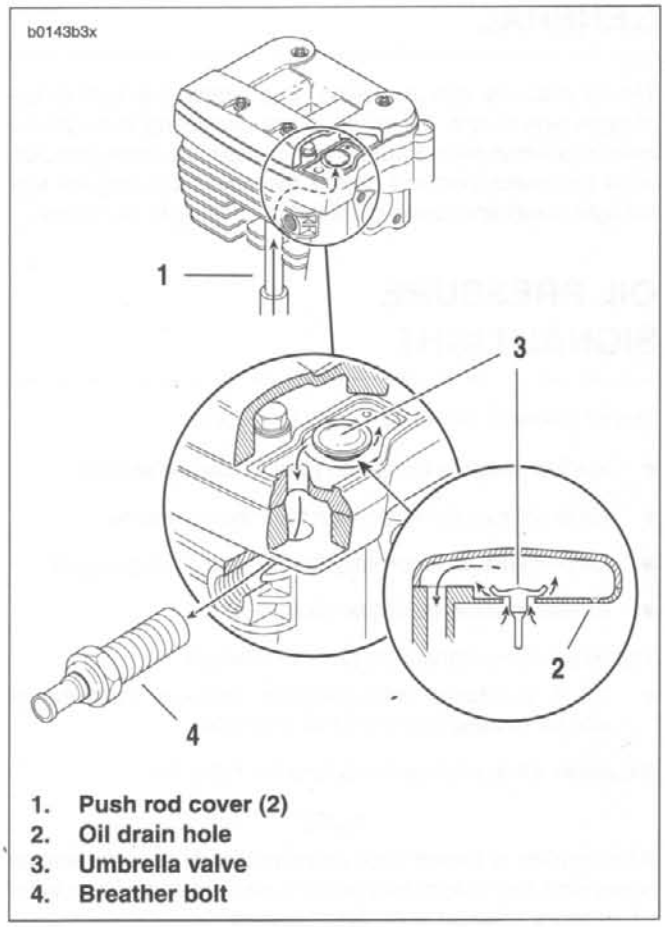
OIL PRESSURE SIGNAL LIGHT	PROBABLE CAUSES
Stays on at speeds above idle.	• Empty oil tank. • Clogged feed line (ice and sludge, freezing temperatures). • Air-bound oil line. • Grounded oil switch wire. • Malfunctioning signal switch. • Diluted oil. • Malfunctioning check valve (see 3.14 OIL FILTER MOUNT).
Flickers at idle.	• Incorrect idle speed. Malfunctioning or improperly installed check valve (see 3.14 OIL FILTER MOUNT).
Does not glow when ignition is turned on (prior to operating engine).	• Malfunctioning signal switch. • Malfunction in wiring. • Burned-out signal bulb. • Dead battery (see NOTE above).

GENERAL

See Figure 3-52. On piston downstroke, a mixture of crankcase air and oil mist is vented up the push rod covers (1) through an umbrella valve (3) in each middle rocker box section.

The oil mist separates from the crankcase air, collects and passes through a small drain hole (2) where it eventually returns to the crankcase.

The crankcase air is routed through a passage in each cylinder head. The air then travels through each air cleaner breather bolt (4). Hoses leading from the air cleaner bolts deposit the air inside the air cleaner's snorkel.



1. **Push rod cover (2)**
2. **Oil drain hole**
3. **Umbrella valve**
4. **Breather bolt**

Figure 3-52. Crankcase Breathing System, Typical Cylinder

OILING SYSTEM (COLOR FOLDOUT) 3.12

NOTE

The following paragraph numbers correspond with the numbered callouts in the INTERNAL ENGINE PASSAGES illustration.

1. Oil is gravity-fed from the oil tank to the gerotor-style oil pump through a **feed hose.** Oil enters the **feed section** and fills a cavity located under the feed pump.

NOTE

See 3.13 OIL PUMP for a complete explanation of the gerotor pump sets.

2. The feed pump transfers oil from the inlet cavity through the **feed hose** to the oil filter mount.
3. Oil flows through the **filter mount cavity** to the oil filter.
4. Oil enters the peripheral cavity of the **oil filter,** passes through the filtering medium into the central cavity of the oil filter, and flows into the filter adapter (fitting which connects filter to filter mount).
5. Adequate oil pressure in the filter mount cavity activates the **oil pressure signal light switch** and shuts off the oil pressure signal light.
6. Oil flowing from the filter adapter opens the **check ball.** The check ball opens at 4-6 psi (28-41 kN/m^2) oil pressure.
7. With the check ball open, oil flows into the **crankcase feed galley.**
8. Oil flows through the feed galley in the crankcase to the tappet blocks and hydraulic lifters. **Cross-drilled passages** intersect the main feed galley and carry oil to each hydraulic lifter.
9. Oil also enters an **intersecting passage** in the gearcase cover. Oil flow is then routed to the crankshaft area.
10. Oil enters a hole in the end of the **pinion gear shaft** and travels to the right flywheel where it is routed through the flywheel to the **crankpin.** Oil is forced through the crankpin to properly lubricate the rod bearing assembly.
11. Oil flows up passages in the **push rods** to the rocker arm shafts and bushings.
12. The valve stems are lubricated by oil supplied through drilled oil holes in the **rocker arms.**
13. Oil collected in the push rod areas of the cylinder heads flows down the **push rod covers,** through drain holes in the **tappet blocks** and into the gearcase. After providing lubrication to the gearcase components, the oil flows to the left side of the oil pump.
14. Feed oil to the rocker area is returned to the crankcase through a **passage** in the head and cylinder.
15. Oil collected in the **sump** is splash-fed to the pistons, cylinder walls and flywheel components.
16. Oil collected in the sump area returns to the scavenge section of the oil pump through a **passage** located in the rear section of the sump. Oil flow to the pump is accomplished by the scavenging effect of the pump and by the pressure created by the downward stroke of the pistons.
17. Return oil fills a **cavity** above the pump's return gears. The return gears pump oil back to the oil tank.
18. A small amount of oil flows from the feed galley in the right crankcase half through a **restricted orifice,** which sprays the oil onto the rear intake cam gear in the gearcase. Oil is transferred to the teeth of all the cam gears through the gear meshing action.

GENERAL

See Figure 3-53. The oil pump consists of two gerotor gear sets, feed and scavenge (return), housed in one pump body. The feed set distributes oil to the engine, the scavenge set returns oil to the tank.

A gerotor-type gear set has two parts — an inner and an outer gerotor. The inner gerotor has one less tooth than the outer gerotor. Both gerotors have fixed centers which are offset to each other.

In a gerotor gear set, oil is transferred from inlet to outlet as it is trapped between the rotating inner and outer gerotors. The illustration below shows the principle of gerotor operation:

1. During the first 180° of rotation, the cavity between inner and outer gerotors gradually increases in size until it reaches its maximum size, equivalent to the full volume of the "missing tooth." The gradually enlarging cavity creates a vacuum into which oil flows from the inlet.
2. During the next 180° of rotation, the size of the cavity decreases forcing oil into the outlet.

See Figure 3-55. Gravity-fed oil from the oil tank enters the pump through the feed hose connector (5). It is forced by the gerotor feed set (7) through a hose to the oil filter. Return oil from the flywheel compartment is drawn back into the pump and is forced by the gerotor scavenge set (9) back to the oil tank.

See INTERNAL ENGINE PASSAGES for oil passages within the engine.

The oil pump seldom needs servicing. Before you disassemble an oil pump suspected of not producing adequate oil pressure, be absolutely certain that all possible related malfunctions have been eliminated:

1. Make sure all oil hose clamps are tight and that hoses are not pinched or damaged.
2. Check oil level and condition of oil in tank. Pressure will be affected if oil is diluted. In freezing weather, proper circulation of oil can be affected if the oil feed hose becomes clogged with ice and sludge.
3. Check for a grounded oil pressure switch wire or faulty switch if oil indicator light fails to go out with engine running.

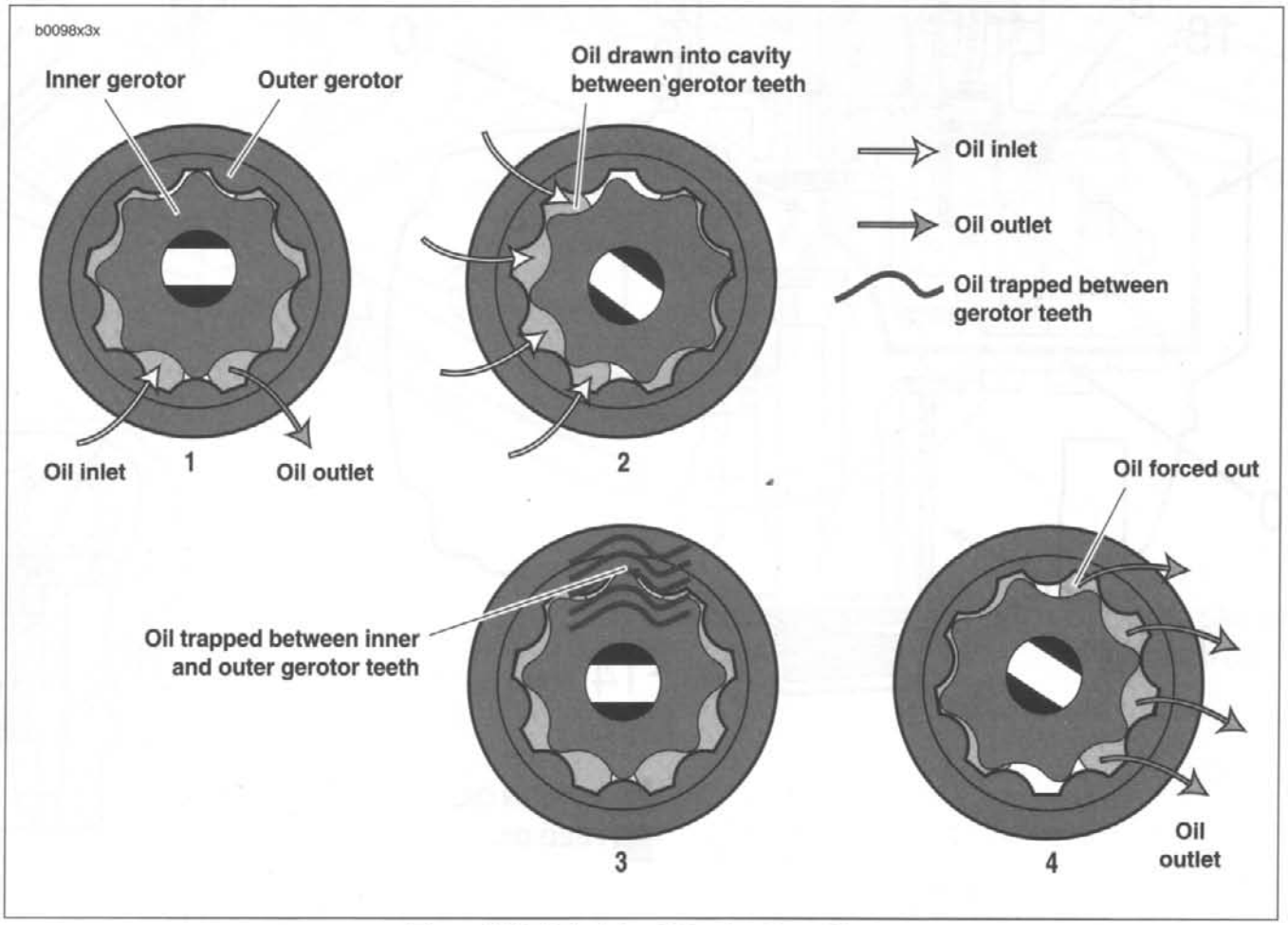
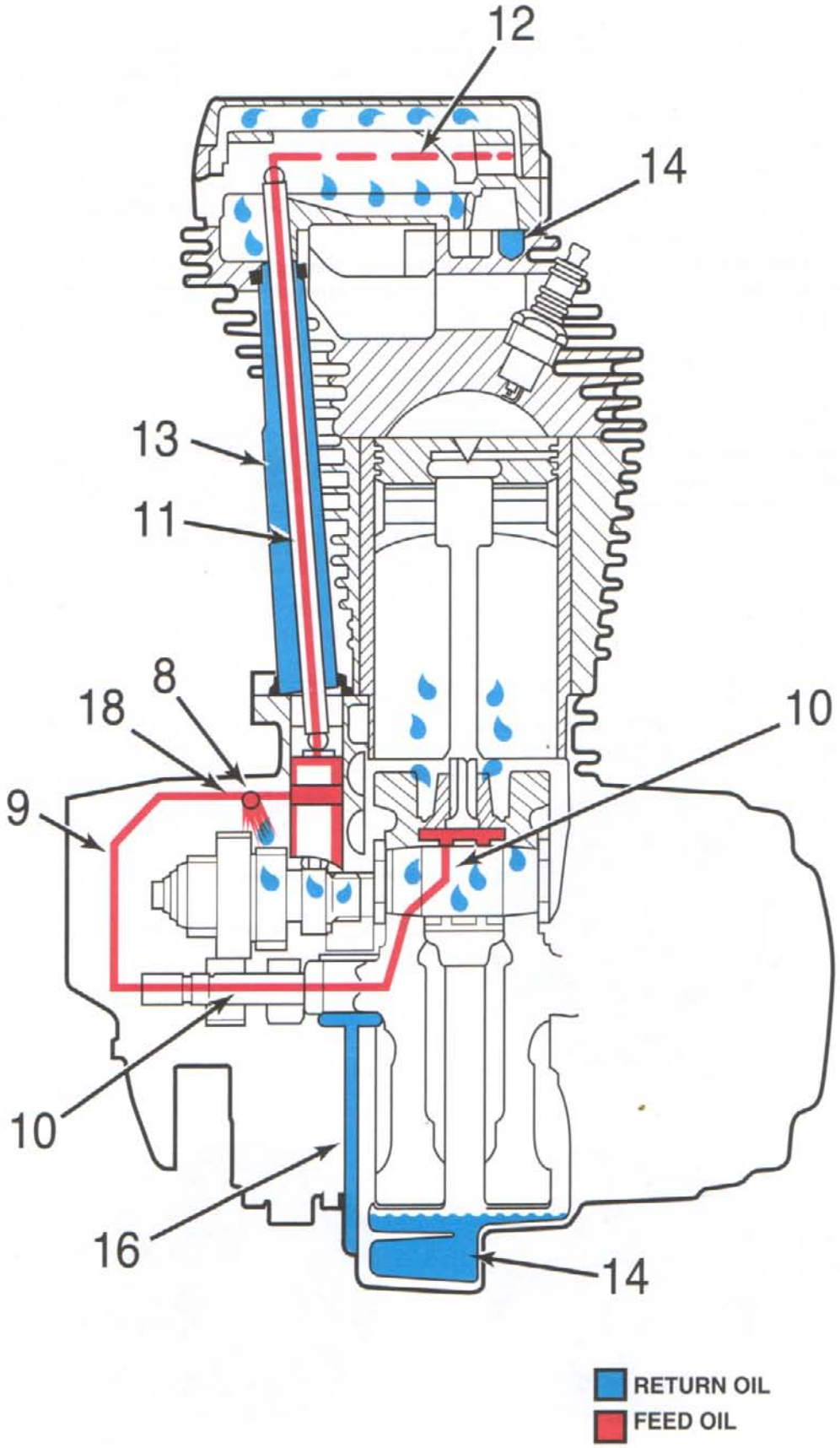


Figure 3-53. Principle of Gerotor Operation


12
14
13
11
18
8
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16
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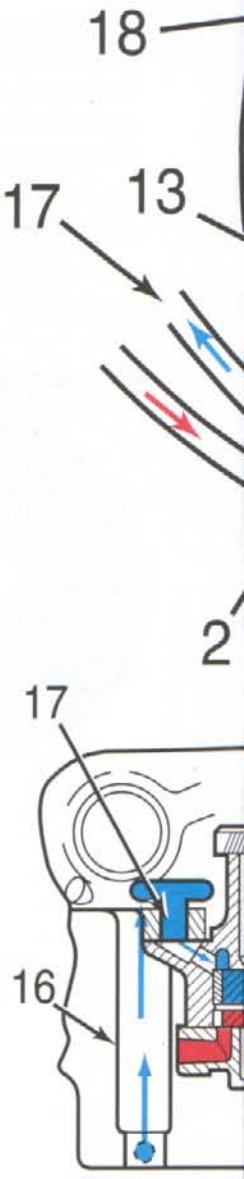
RETURN OIL
FEED OIL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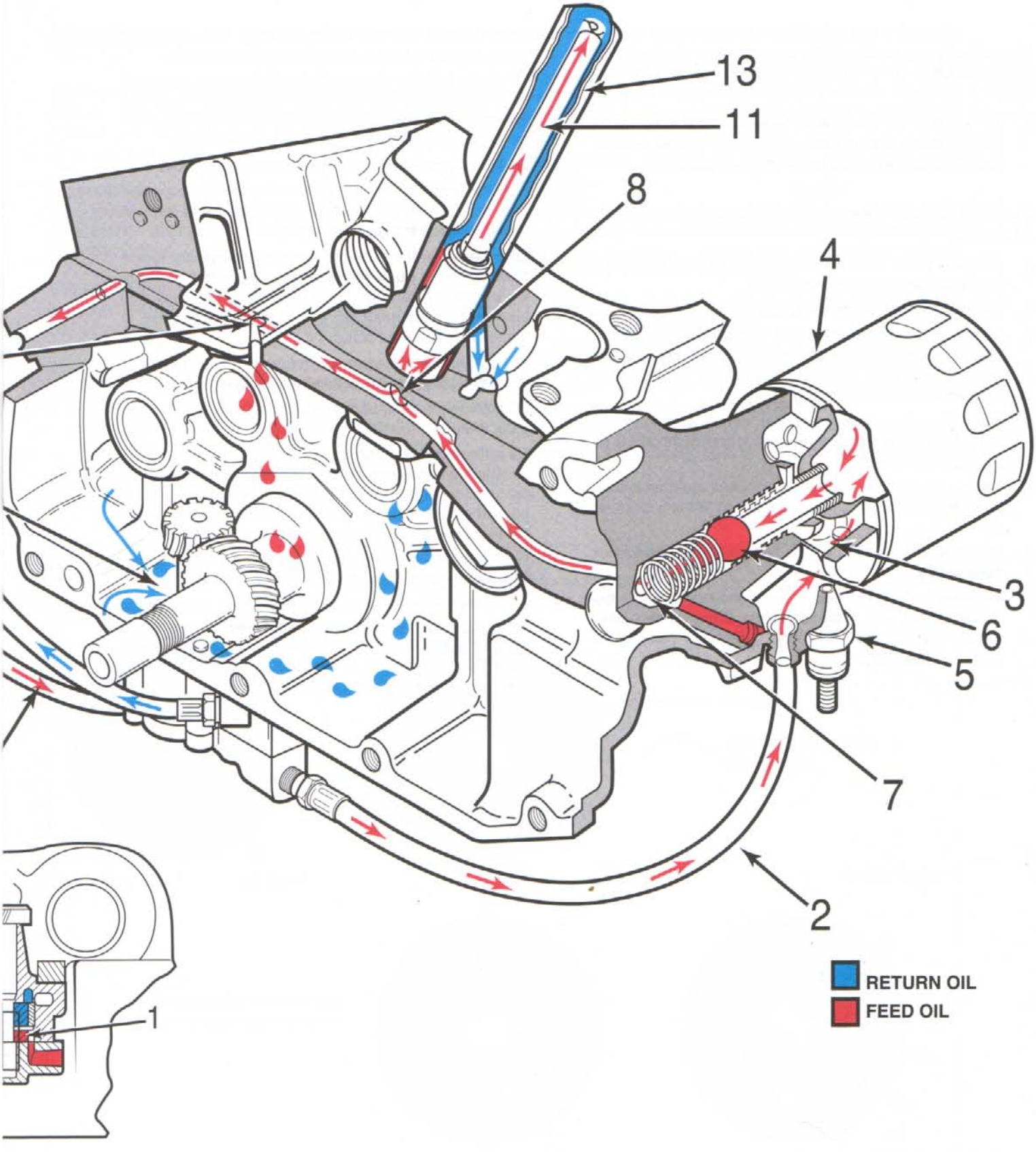


REMOVAL/DISASSEMBLY

NOTE

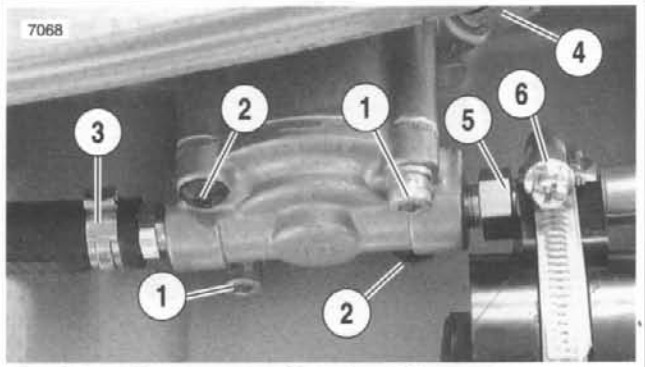
Oil pump can be removed with engine in frame and without removing gearcase cover.

1. Drain oil tank. See 1.6 ENGINE LUBRICATION SYSTEM.
2. See Figure 3-54. Disconnect feed hose (3).
3. Remove clamp (6) from filter hose. Detach oil filter hose connection (5).

NOTE

Loosen nut on oil filter hose connection (5) and then remove pressurized hose.

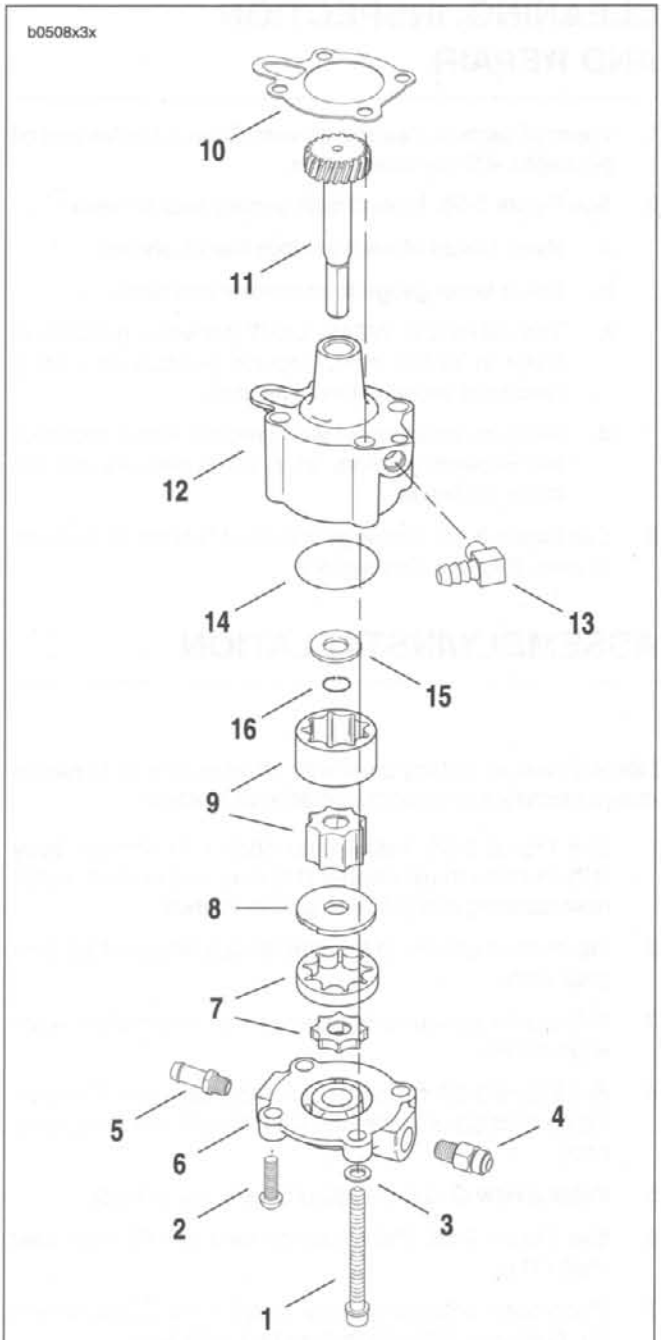
4. Carefully remove mounting screws and washers (1). Pump will drop with screws removed. Discard mounting gasket.
5. Remove clamp and detach return hose connection (4).



1. **Mounting screw and washer (2)**
2. **Cover TORX screw (2)**
3. **Feed hose connection**
4. **Return hose connection**
5. **Oil filter hose connection**
6. **Clamp**

Figure 3-54. Oil Pump Hardware

6. See Figure 3-55. Remove cover TORX screws (2). Lift cover (6) off body (12). Remove and discard O-ring (14).
7. Slide both pieces of gerotor feed set (7), separator plate (8) and both pieces of gerotor scavenge set (9) off gear shaft (11).
8. Remove and discard retaining ring (16). Remove thrust washer (15) and gear shaft (11).



1. **Mounting screw (2)**
2. **Cover TORX screw (2)**
3. **Washer (2)**
4. **Oil filter mount connector**
5. **Feed hose connector**
6. **Cover**
7. **Gerotor feed set**
8. **Gerotor separator plate**
9. **Gerotor scavenge set**
10. **Mounting gasket**
11. **Gear shaft**
12. **Body**
13. **Return hose elbow connector**
14. **O-ring**
15. **Thrust washer**
16. **Retaining ring**

Figure 3-55. Oil Pump

CLEANING, INSPECTION AND REPAIR

1. Clean all parts in cleaning solvent. Blow out holes and oil passages with compressed air.
2. See Figure 3-56. Inspect both gerotor sets for wear.
   a. Mesh pieces of each set together as shown.
   b. Use a feeler gauge to determine clearance.
   c. The SERVICE WEAR LIMIT between gerotors is 0.004 in. (0.102 mm). Replace gerotors as a set if clearance exceeds this dimension.
   d. Measure thickness of feed gerotors with a micrometer. Replace gerotors as a set if they are not the same thickness.
3. See Figure 3-55. Check gear shaft (11) teeth for damage or wear. Replace if necessary.

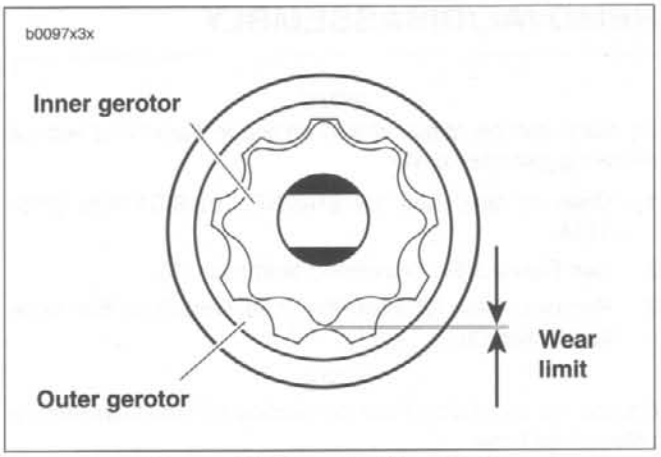


Figure 3-56. Gerotor Wear Limits

ASSEMBLY/INSTALLATION

NOTE

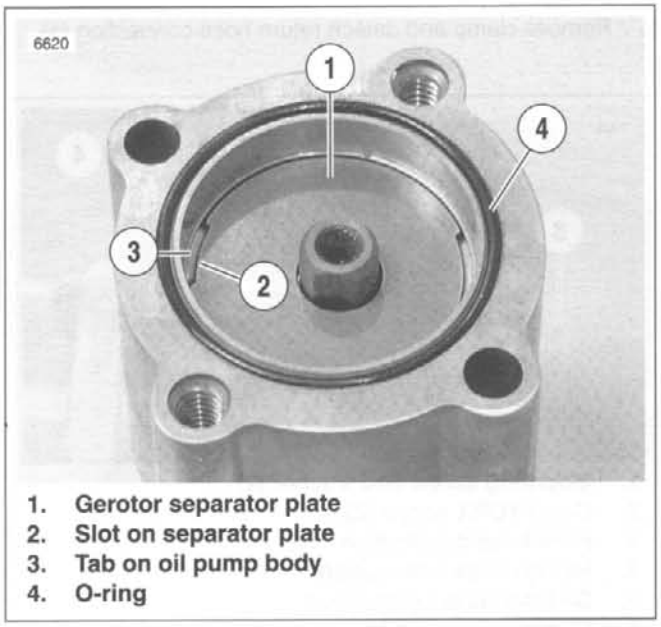
Liberally coat all moving parts with clean engine oil to ensure easy assembly and smooth operation at start-up.

1. See Figure 3-55. Install gear shaft (11) through body (12). Position thrust washer (15) over end of shaft. Install **new** retaining ring (16) into groove in shaft.
2. Insert inner gerotor of the gerotor scavenge set (9) over gear shaft.
3. Place outer gerotor over inner gerotor to complete scavenge set (9).
4. See Figure 3-57. Install gerotor separator plate (1) by lining up slots (2) on perimeter with tabs (3) inside oil pump body.
5. Install a **new** O-ring (4) into groove in pump body.
6. See Figure 3-55. Place gerotor feed set (7) over gear shaft (11).
7. Place cover onto pump body. Install cover TORX screws (2). Tighten to 125-150 **in-lbs** (14.1-16.9 Nm).
8. Place **new** mounting gasket (10) in position.

NOTE

*Use **new** hose clamps. If fittings were removed, use TEFLON® PIPE SEALANT or HYLOMAR® on fitting threads.*

9. See Figure 3-54. Attach return hose connection (4).
10. Secure pump to crankcase with mounting screws (1) and washers. Tighten to 125-150 **in-lbs** (14.1-16.9 Nm).
11. Attach feed hose (3) and oil filter hose connection (5).
12. Attach clamp (6) and canister to hose.
13. Check engine oil level. Add oil to correct level if needed. See 1.6 ENGINE LUBRICATION SYSTEM.



1. **Gerotor separator plate**
2. **Slot on separator plate**
3. **Tab on oil pump body**
4. **O-ring**

Figure 3-57. Separator Plate Slots

OIL FILTER MOUNT 3.14

GENERAL

See Figure 3-58. Oil is pressure-fed from the oil pump to the filter mount (4) via a hose (5). Oil travels through the filter mount into the filter via outer filter holes.

Adequate oil pressure activates the oil pressure indicator switch (6) in the filter mount, which turns off the oil pressure indicator lamp.

The check ball (2) in the filter adapter (1) "opens" at 4-6 psi (28-41 kN/m^2) oil pressure. Filtered oil leaves the filter, flowing past the check ball.

DISASSEMBLY

1. Drain oil tank and remove filter. See 1.6 ENGINE LUBRICATION SYSTEM.
2. Remove filter adapter (1) from filter mount (4). Remove check ball (2) and spring (3).
3. Detach indicator lamp wire (7) from oil pressure indicator switch (6). Remove switch using OIL PRESSURE SENDING UNIT WRENCH (Part No. HD-41675).

CLEANING/INSPECTION

Thoroughly clean all parts in cleaning solvent. Blow out holes and passages using compressed air.

ASSEMBLY

NOTE

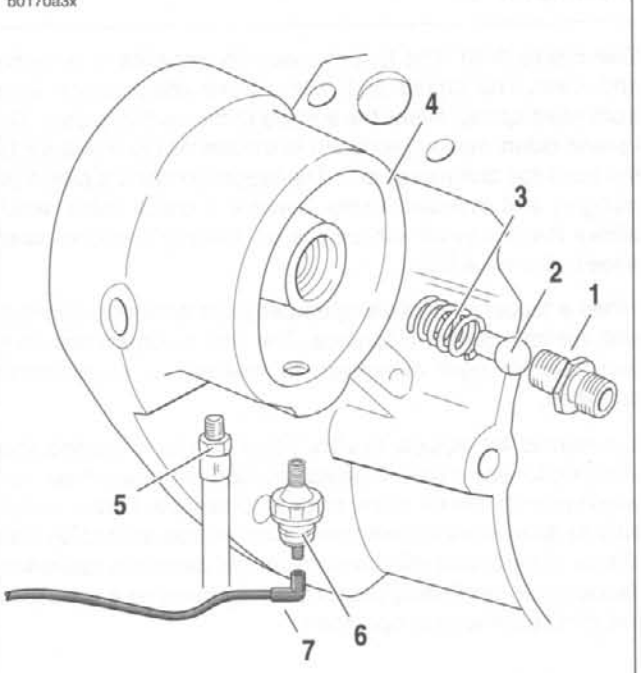
Use TEFLON PIPE SEALANT or HYLOMAR on all fittings installed to oil filter mount.

1. Install oil pressure indicator switch (6) using OIL PRESSURE SENDING UNIT WRENCH (Part No. HD-41675). Tighten to 4-6 ft-lbs (5.4-8.1 Nm).

NOTE

The filter adapter (1) has identical ends; either end may be installed into the filter mount (4).

2. Apply LOCTITE THREADLOCKER 243 (blue) to the threads on that end of the filter adapter (1) which is installed into filter mount (4). Do not apply LOCTITE to adapter threads on filter element side.



1. **Filter adapter**
2. **Check ball**
3. **Spring**
4. **Filter mount (part of right crankcase half)**
5. **Hose from oil pump**
6. **Oil pressure indicator switch**
7. **Indicator lamp wire**

Figure 3-58. Oil Filter Mount

3. Install filter mount components.
   a. Place spring (3) and check ball (2) into threaded hole at center of mount (4).
   b. Push threaded end of filter adapter (with LOCTITE) (1) against check ball to compress spring.
   c. Screw adapter into threaded hole. Tighten to 8-12 ft-lbs (10.8-16.3 Nm).
4. Attach indicator lamp wire (7).
5. Install a **new** filter and fill oil tank with proper oil. See 1.6 ENGINE LUBRICATION SYSTEM.

GENERAL

See Figure 3-59. The tappet assembly consists of a tappet and roller. The tappet and roller, under compression force from valve spring, follow the surface of the revolving cam. The up-and-down motion produced is transmitted to the valve by the push rod and rocker arm. The tappet contains a piston (or plunger) and cylinder; it also contains a check valve, which allows the unit to fill with engine oil, thereby reducing clearance in the valve train.

When a tappet is functioning properly, the assembly operates with minimal tappet clearance. The unit automatically compensates for heat expansion to maintain a no-clearance condition.

It is normal for tappets to click when engine is started after standing for some time. Tappets have a definite leakdown rate which permits the oil in the tappets to escape. This is necessary to allow units to compensate for various expansion conditions of parts and still maintain correct clearance operation. Tappets are functioning properly if they become quiet after a few minutes of engine operation.

REMOVAL

1. Clean all dirt from around crankcase. Blow loose particles from area with compressed air.
2. Remove the upper, middle, and lower rocker covers. See 3.5 CYLINDER HEAD. Pull each push rod upward through top of cylinder head.
3. See Figure 3-61. Remove both push rod covers (7).
   a. Remove screw (11) and washer (13).
   b. Lift retainer (9) and seal (8) upward a few inches on push rod cover (7).
   c. Push upward on push rod cover while pulling bottom of cover clear of crankcase. Remove cover.
4. Remove both valve tappets (6).
   a. Remove screw (5), washer (14) and plate (4).
   b. Pull and discard O-rings (3) from ends of pins (2). Grasp pins (2) and pull from crankcase. Use a pliers if necessary.
   c. Remove tappet from crankcase bore using a thin-bladed screwdriver. Mark the location and orientation (front/back) of each tappet.

CLEANING/INSPECTION

1. Clean all parts, except roller/tappet assembly, thoroughly in solvent. Blow dry with compressed air.

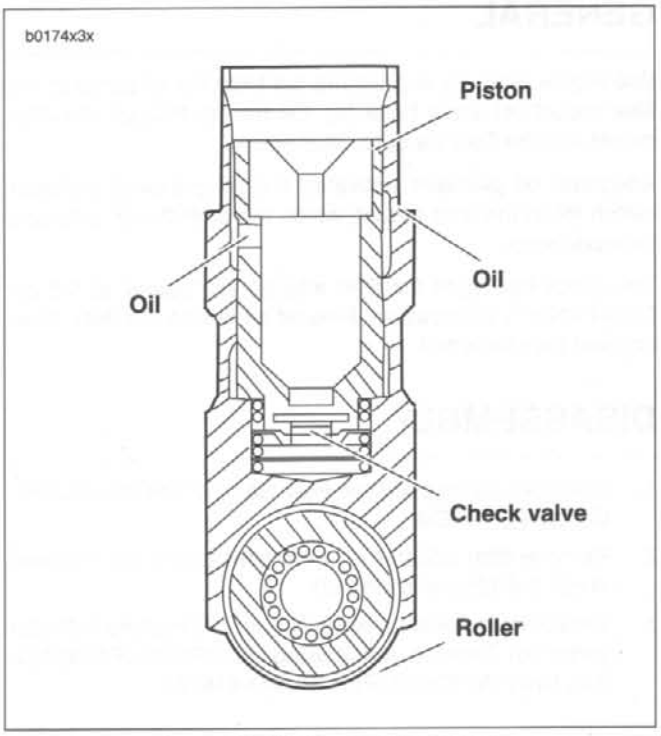


Figure 3-59. Tappet Assembly

NOTE

Inside and outside micrometers used for measuring tappets and tappet guides must be calibrated to ensure accurate readings.

2. Inspect valve tappets for excessive clearance in guide. Accurately measure tappet bore inner diameter with a gauge.
   a. Clearance should be within 0.0008-0.0020 in. (0.0203-0.0508 mm).
   b. Fit a **new** tappet and/or replace crankcases if clearance exceeds SERVICE WEAR LIMIT of 0.0030 in. (0.076 mm).
3. Check tappet roller freeplay.
   a. Roller clearance on pin should be within 0.0006-0.0010 in. (0.0152-0.0254 mm).
   b. Replace tappets if clearance exceeds SERVICE WEAR LIMIT of 0.0015 in. (0.0381 mm).
4. Check tappet roller end clearance.
   a. End clearance should be within 0.008-0.022 in. (0.203-0.559 mm).
   b. Replace tappets if clearance exceeds SERVICE WEAR LIMIT of 0.026 in. (0.660 mm).
5. Soak tappets in clean engine oil. Keep covered until assembly.

INSTALLATION

1. See Figure 3-60. Rotate engine so that both tappets, from the cylinder being serviced, will be installed on the base circle (1) of the cam.

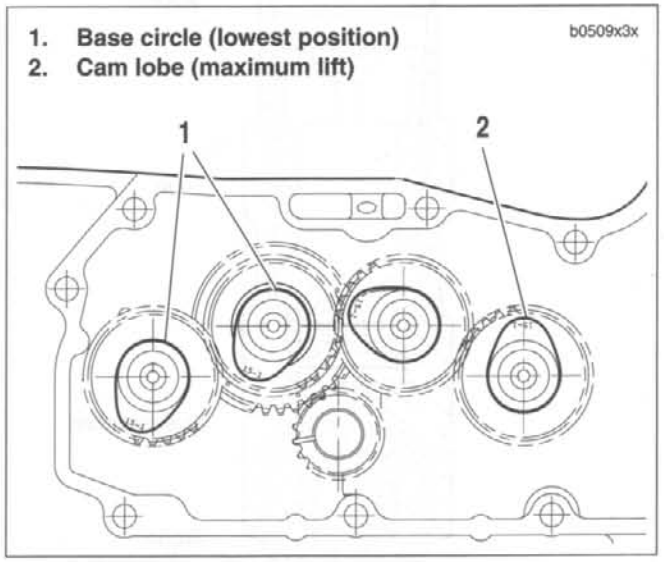
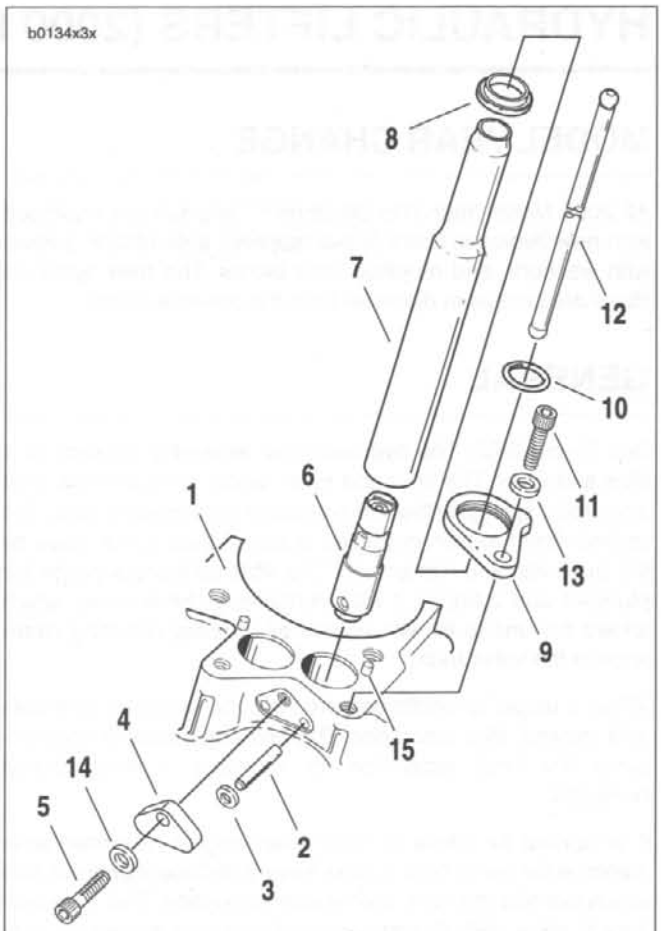


Figure 3-60. Base Circle

2. Apply a liberal amount of engine oil to each tappet assembly (especially the roller needles) for smooth initial operation.
3. See Figure 3-61. Insert tappet (6) into bore in crankcase (1). Rotate tappet so that flats at upper end of tappet face the front and rear of the engine. If the tappet is installed incorrectly, pins (2) cannot be inserted.
4. Secure tappets in place.
   a. Insert pins (2) in the holes in crankcase.
   b. Place **new** O-rings (3) over ends of pins.
   c. Install plate (4) using screw (5) with washer (14). Tighten to 80-110 **in-lbs** (9.0-12.4 Nm).
5. Install push rod covers.
   a. Slide **new** seal (8) and retainer (9) over top of push rod cover (7).
   b. Position **new** O-ring (10) at top of push rod cover.
   c. Hold cover at an angle and insert top through hole in cylinder head. Push up on cover while aligning bottom of cover with tappet bore in crankcase.
   d. Lower retainer (9) with seal (8) onto crankcase, aligning locating pin (15) with hole in retainer.
   e. Insert screw (11) with washer (13) through hole in retainer (9). Thread screw (11) into tapped hole in crankcase. Tighten to 15-18 ft-lbs (20.3-24.4 Nm).
6. Install push rods and rocker covers. See INSTALLATION.



1. **Right crankcase half**
2. **Pin (2)**
3. **O-ring (2)**
4. **Plate**
5. **Screw**
6. **Tappet lifter (2)**
7. **Push rod cover (2)**
8. **Seal (2)**
9. **Retainer (2)**
10. **O-ring (2)**
11. **Screw (2)**
12. **Push rod (2)**
13. **Washer (2)**
14. **Washer**
15. **Locating pin (2)**

Figure 3-61. Valve Tappet Service

HYDRAULIC LIFTERS (2000 MODELS) 3.16

MODEL YEAR CHANGE

All 2000 Model Year Thunderstorm™ engines are equipped with **new** hydraulic lifters (valve tappets), anti-rotation screws with washers, and modified lifter blocks. The **new** hydraulic lifters are smaller in diameter than the previous lifters.

GENERAL

See Figure 3-62. The hydraulic lifter assembly consists of a lifter and roller. The lifter and roller, under compression force from valve spring, follow the surface of the revolving cam. The up-and-down motion produced is transmitted to the valve by the push rod and rocker arm. The lifter contains a piston (or plunger) and cylinder; it also contains a check valve, which allows the unit to fill with engine oil, thereby reducing clearance in the valve train.

When a tappet is functioning properly, the assembly operates with minimal lifter clearance. The unit automatically compensates for heat expansion to maintain a no-clearance condition.

It is normal for lifters to click when engine is started after standing for some time. Lifters have a definite leakdown rate which permits the oil in the tappets to escape. This is necessary to allow units to compensate for various expansion conditions of parts and still maintain correct clearance operation. Lifters are functioning properly if they become quiet after a few minutes of engine operation.

REMOVAL

1. Clean all dirt from around crankcase. Blow loose particles from area with compressed air.
2. Remove the upper, middle, and lower rocker covers. See 3.5 CYLINDER HEAD. Pull each push rod upward through top of cylinder head.
3. See Figure 3-64. Remove both push rod covers (4).
   a. Remove screw (8) and washer (10).
   b. Lift retainer (6) and seal (7) upward a few inches on push rod cover (4).
   c. Push upward on push rod cover while pulling bottom of cover clear of crankcase. Remove cover.
4. Remove both hydraulic lifters (3).
   a. Remove two anti-rotation screws with washers (2).
   b. Remove lifters (3) from crankcase bore using a thin-bladed screwdriver. Mark the location and orientation (front/back) of each tappet.

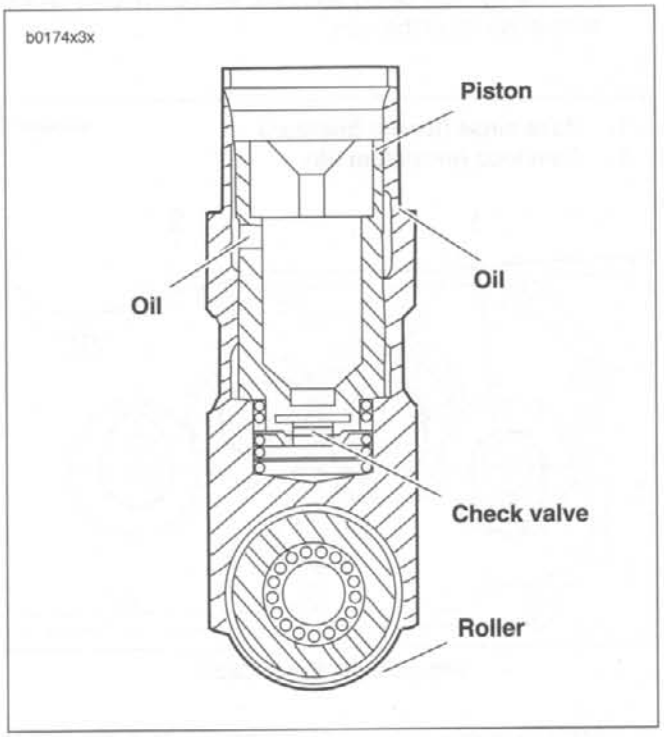


Figure 3-62. Lifter Assembly (Typical)

CLEANING/INSPECTION

1. Clean all parts, except roller/lifter assembly, thoroughly in solvent. Blow dry with compressed air.

NOTE

Inside and outside micrometers used for measuring lifters and lifter guides must be calibrated to ensure accurate readings.

2. Inspect hydraulic lifters for excessive clearance in guide. Accurately measure lifter bore inner diameter with a gauge.
   a. Clearance should be within 0.0008-0.0020 in. (0.0203-0.0508 mm).
   b. Fit a **new** lifter and/or replace crankcases if clearance exceeds SERVICE WEAR LIMIT of 0.0030 in. (0.076 mm).
3. Check lifter roller freeplay.
   a. Roller clearance on pin should be within 0.0006-0.0010 in. (0.0152-0.0254 mm).
   b. Replace lifters if clearance exceeds SERVICE WEAR LIMIT of 0.0015 in. (0.0381 mm).
4. Check lifter roller end clearance.
   a. End clearance should be within 0.008-0.022 in. (0.203-0.559 mm).
   b. Replace tappets if clearance exceeds SERVICE WEAR LIMIT of 0.026 in. (0.660 mm).
5. Soak lifters in clean engine oil. Keep covered until assembly.

INSTALLATION

1. See Figure 3-63. Rotate engine so that both lifters, from the cylinder being serviced, will be installed on the base circle (1) of the cam.

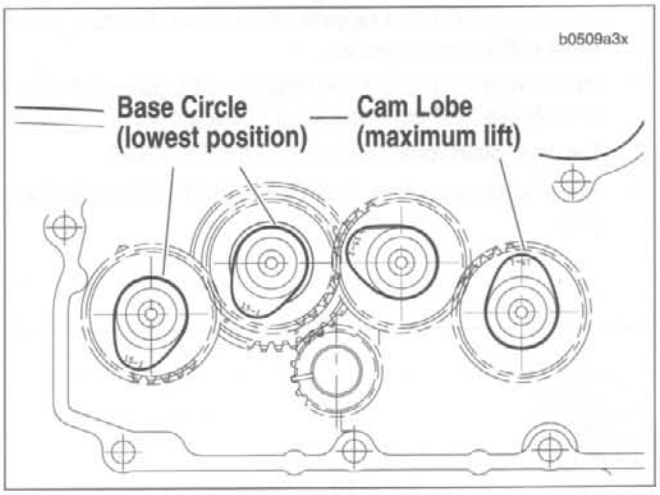
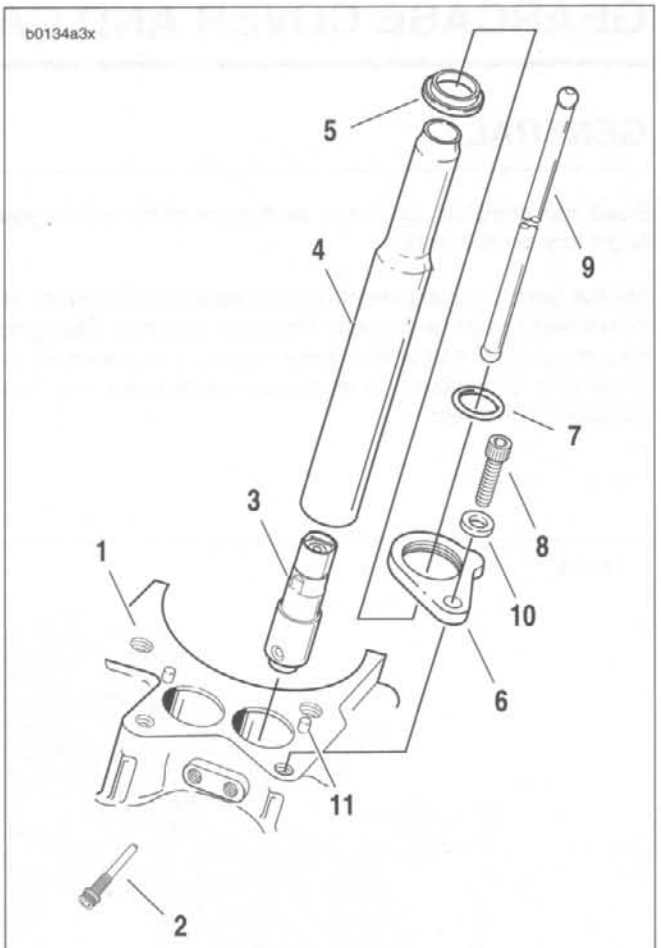


Figure 3-63. Base Circle

2. Apply a liberal amount of engine oil to each lifter assembly (especially the roller needles) for smooth initial operation.
3. See Figure 3-64. Insert lifter (3) into bore in crankcase (1) with lifter oil hole facing towards the oil trough. Rotate lifter so that flats at upper end of lifter faces the front and rear of the engine. If the lifter is installed incorrectly, anti-rotation screws (2) cannot be inserted.
4. Secure lifters in place.
   a. Insert anti-rotation screws with washers (2) in the threaded holes in crankcase.
   b. Tighten anti-rotation screws to 80-110 **in-lbs** (9.0-12.4 Nm)
5. Install push rod covers.
   a. Slide **new** seal (5) and retainer (6) over top of push rod cover (4).
   b. Position **new** O-ring (7) at top of push rod cover.
   c. Hold cover at an angle and insert top through hole in cylinder head. Push up on cover while aligning bottom of cover with lifter bore in crankcase.
   d. Lower retainer (6) with seal (5) onto crankcase, aligning locating pin (11) with hole in retainer.
   e. Insert screw (8) with washer (10) through hole in retainer (6). Thread screw (8) into tapped hole in crankcase. Tighten to 15-18 ft-lbs (20.3-24.4 Nm).
6. Install push rods and rocker covers. See 3.5 CYLINDER HEAD.



1. **Right Crankcase Half**
2. **Anti-rotation Screws with Washers (2)**
3. **Hydraulic Lifter (2)**
4. **Push Rod Cover (2)**
5. **Seal (2)**
6. **Retainer (2)**
7. **O-ring (2)**
8. **Screw (2)**
9. **Push Rod (2)**
10. **Washer (2)**
11. **Locating Pin (2)**

Figure 3-64. Hydraulic Lifter Service

GEARCASE COVER AND CAM GEARS (1999 MODELS) 3.17

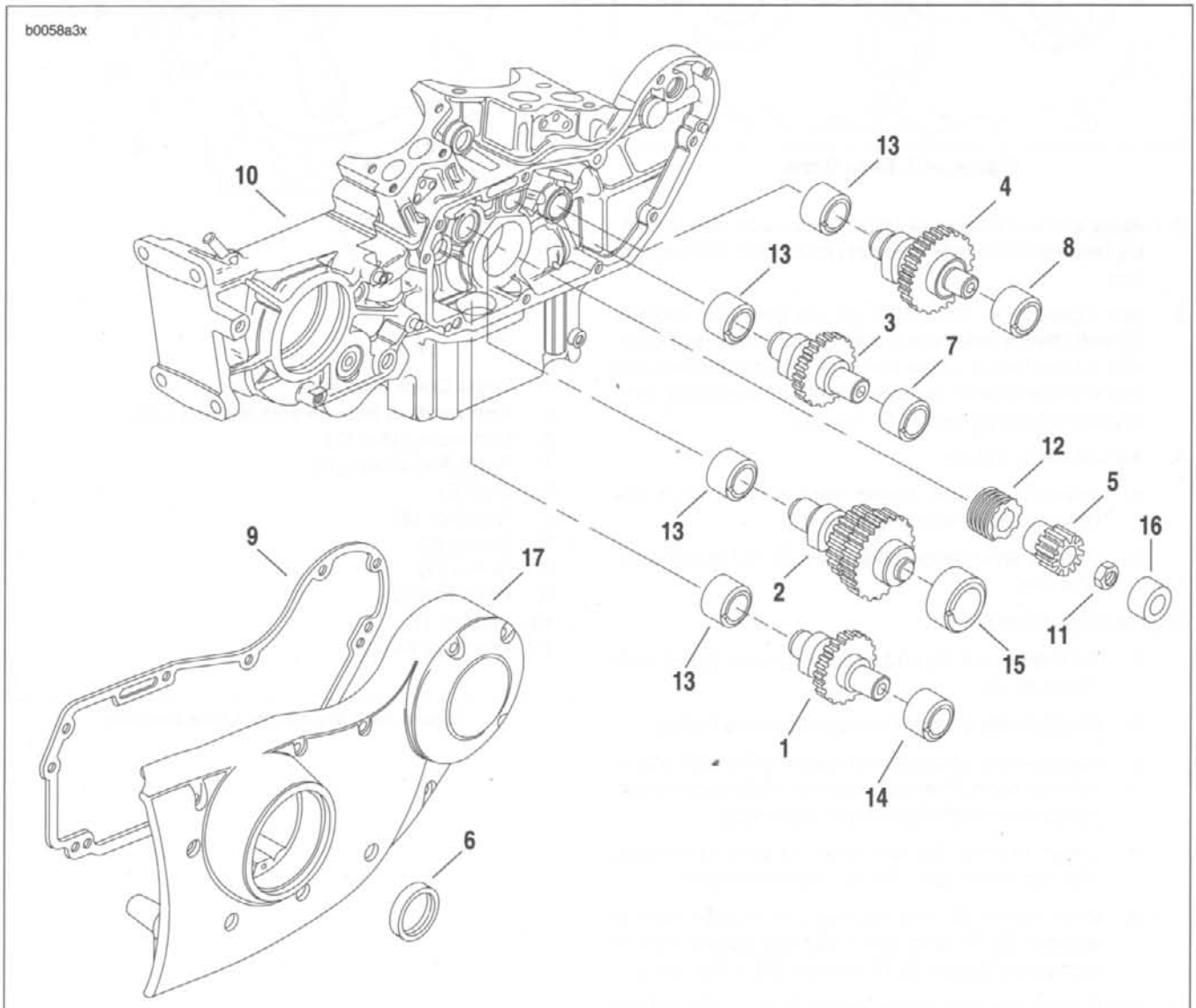
GENERAL

Read the complete gearcase section carefully before you begin any service work.

For the gearcase components to operate at their optimum, all components must be properly fitted and matched. Changing one component can affect many others. It is important to know and understand all inspection procedures and how components interact.

REMOVAL/DISASSEMBLY

1. See Figure 3-65. Thoroughly clean area around gearcase cover (17) and tappets. Blow loose dirt from crankcase with compressed air.
2. Remove any parts that will interfere with gearcase disassembly (i.e., exhaust header, air cleaner, etc.).
3. Remove push rods. See 3.5 CYLINDER HEAD.
4. Remove tappets. See 3.15 VALVE TAPPETS (1999 models).



1. Rear exhaust cam gear
2. Rear intake cam gear
3. Front intake cam gear
4. Front exhaust cam gear
5. Pinion gear
6. Seal
7. Front intake cam gear bushing
8. Front exhaust cam gear bushing
9. Gearcase cover gasket
10. Right crankcase half
11. Nut
12. Oil pump drive gear
13. Cam gear bushing (4)
14. Rear exhaust cam gear bushing
15. Rear intake cam gear bushing
16. Pinion shaft bushing
17. Gearcase cover

Figure 3-65. Gearcase and Valve Train Components

5. Check for minimum cam gear end play. Record readings.
6. Remove cam position sensor from gearcase cover. See 4.29 CAM POSITION SENSOR AND ROTOR.
7. Place a pan under gearcase to collect oil. Remove cover screws. Carefully remove gearcase cover. Discard old gasket (9).

NOTE

If cover does not come loose on removal of screws, tap lightly with a plastic hammer. Never pry cover off.

8. Remove cam gears (1, 2, 3 and 4). Carefully mark each component to ensure correct installation.

NOTE

Nut (11) is secured by LOCTITE THREADLOCKER 262 (red) on the nut threads.

9. Remove nut (11). Slide pinion gear (5) and oil pump drive gear (12) off pinion shaft.

CLEANING, INSPECTION AND REPAIR

1. Thoroughly clean gearcase compartment, gearcase cover and gears in solvent to remove oil and carbon deposits.
2. Blow out all cover oil passages and bushings with compressed air.
3. Clean old gasket material from gearcase and cover faces with cleaning solvent.

Cam and Pinion Gear Identification, Inspection, and Selection

See Figure 3-66. Cam lobes are stamped with the number "15" followed by a number (1, 2, 3 or 4). The number "15" indicates model year application; the number identifies the cam location/function:

15-1 = rear exhaust
15-2 = rear intake
15-3 = front intake
15-4 = front exhaust

Use only "15" cams on 1998 models.

See Figure 3-67. Measure the gear diameter with a micrometer over 0.108 in. (2.743 mm) diameter gauge pins on opposite sides of the gear. The pins are of the proper size to fit between the contacting surfaces of the gear teeth. Gear diameter should be measured in at least two places 90° apart. Use GAUGE PIN SET (Part No. HD-38361) when measuring pinion and cam gear sizes.

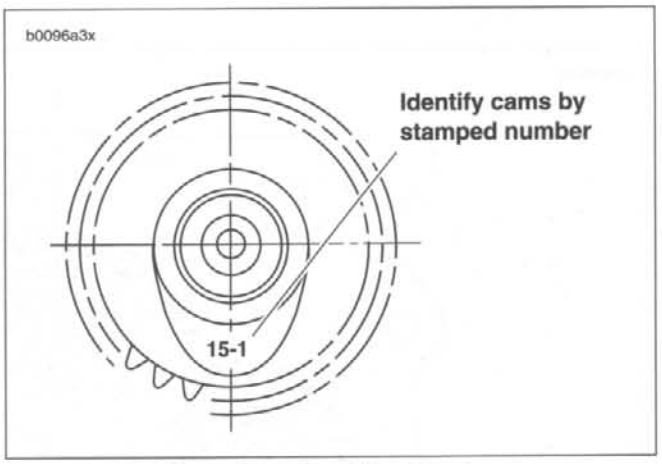


Figure 3-66. Cam Identification

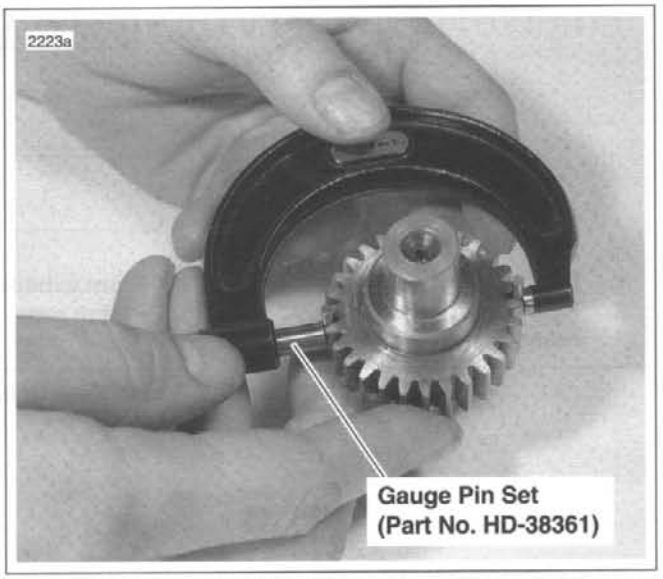


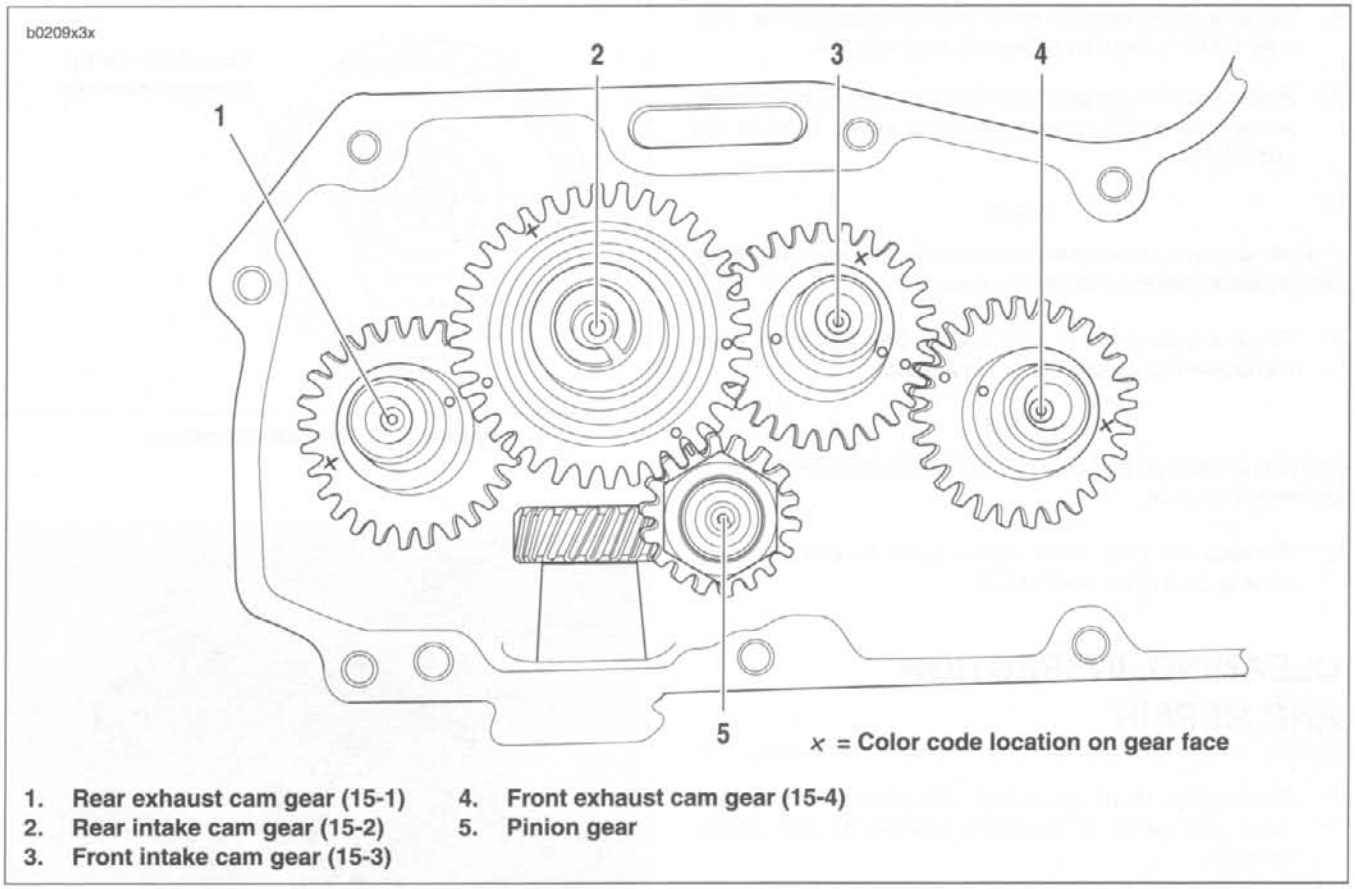
Figure 3-67. Measuring Gear Size

Cam and pinion gears are individually selected for each specific gear cover through sophisticated computer-aided measuring techniques in a controlled environment. Each gear is assigned an individual color code based on its diameter (measured with gauge pins). When cam and/or pinion gears are replaced, always use the same color code as found on gears being replaced to ensure that the gear operation remains as quiet as possible. For location of cam and pinion gear color codes, see Figure 3-68.

NOTE

On flywheel pinion shaft, a paint dot is located on the shaft perimeter near the centerline of the keyway. This dot identifies the pinion shaft inner race size. Do not use this dot to select pinion gear size.

See Table 3-10. Compare the previously measured diameter of each gear with the specifications (listed in inches) shown in the table to determine amount of wear on gear teeth.



1. Rear exhaust cam gear (15-1)
2. Rear intake cam gear (15-2)
3. Front intake cam gear (15-3)
4. Front exhaust cam gear (15-4)
5. Pinion gear

Figure 3-68. Cam and Pinion Gear Color Code Location and Timing Mark Indexing

NOTE

Prior to changing any cam gears, check gear shaft fit within corresponding bushings. Worn bushings can cause excessive backlash.

Table 3-10. Cam and Pinion Gear Color Code and Diameter

GEAR NO. & POSITION	1	2 INBOARD	2 OUT-BOARD	3	4	5
COLOR CODE (1 paint dot)	Rear Exhaust	Rear Intake	Rear Intake	Front Intake	Front Exhaust	Pinion
BROWN	1.9005-1.9009 (48.272-48.283)	1.9035-1.9039 (48.349-48.359)	2.4021-2.4025 (61.013-61.023)	1.9005-1.9009 (48.272-48.283)	1.9035-1.9039 (48.349-48.359)	1.2753-1.2756 (32.393-32.400)
BLUE	1.9010-1.9014 (48.285-48.295)	1.9030-1.9034 (48.336-48.346)	2.4026-2.4030 (61.026-61.036)	1.9010-1.9014 (48.285-48.295)	1.9030-1.9034 (48.336-48.346)	1.2749-1.2752 (32.382-32.390)
RED	1.9015-1.9019 (48.298-48.308)	1.9025-1.9029 (48.323-48.333)	2.4031-2.4035 (61.038-61.049)	1.9015-1.9019 (48.298-48.308)	1.9025-1.9029 (48.323-48.333)	1.2745-1.2748 (32.372-32.380)
WHITE	1.9020-1.9024 (48.310-48.321)	1.9020-1.9024 (48.310-48.321)	2.4036-2.4040 (61.051-61.061)	1.9020-1.9024 (48.310-48.321)	1.9020-1.9024 (48.310-48.321)	1.2741-1.2744 (32.362-32.369)
GREEN	1.9025-1.9029 (48.323-48.333)	1.9015-1.9019 (48.298-48.308)	2.4041-2.4045 (61.064-61.074)	1.9025-1.9029 (48.323-48.333)	1.9015-1.9019 (48.298-48.308)	1.2737-1.2740 (32.352-32.359)
YELLOW	1.9030-1.9034 (48.336-48.346)	1.9010-1.9014 (48.285-48.295)	2.4046-2.4050 (61.076-61.087)	1.9030-1.9034 (48.336-48.346)	1.9010-1.9014 (48.285-48.295)	1.2733-1.2736 (32.341-32.349)
BLACK	1.9035-1.9039 (48.349-48.359)	1.9005-1.9009 (48.272-48.283)	2.4051-2.4055 (61.089-61.099)	1.9035-1.9039 (48.349-48.359)	1.9005-1.9009 (48.272-48.283)	1.2729-1.2732 (32.331-32.339)

Bushing Inspection and Removal

1. See Figure 3-65. Bushings (7, 8, 13, 14, 15 and 16) are press fit in gearcase cover (17) and crankcase. Inspect each bushing against its corresponding cam gear shaft or pinion gear shaft. See Table 3-11.

Table 3-11. Gear Shaft Specifications

GEAR SHAFT	CORRECT CLEARANCE	SERVICE WEAR LIMIT
Cam	0.0007-0.0022 in. (0.0178-0.0559 mm)	0.003 in. (0.076 mm)
Pinion	0.0023-0.0043 in. (0.0584-0.1092 mm)	0.0050 in. (0.1270 mm)

2. See Figure 3-69. Use a BUSHING AND BEARING PULLER (Part No. HD-95760-69A) to remove bushings from gearcase cover and crankcase.

Bushing Installation

NOTE

Installing and reaming crankcase and gearcase cover bushings may alter the center distances between mating gears and may result in an increase in gear noise. For quiet-running gears, the gears should be matched to the center distances.

CAM GEAR BUSHINGS IN RIGHT CRANKCASE HALF

1. See Figure 3-71. Each cam gear bushing (1), to be installed in right crankcase half (2), must be positioned in crankcase bore with its oiling slot at exact top of bore (12 o'clock position).
2. Using an arbor press, install each bushing in its crankcase bore so that bushing shoulder contacts crankcase boss.
3. After you install a **new** bushing in right crankcase half, ream the bushing to correct size. See BUSHING REAMING on page 3-48.

CAM GEAR BUSHINGS (EXCEPT REAR INTAKE BUSHING) IN GEARCASE COVER

1. See Figure 3-65. Using an arbor press, install each bushing (7, 8 and 14) in its gearcase cover (17) bore so that bushing shoulder contacts cover boss. Orient each bushing so the oiling slot is at the 9 o'clock position within the gearcase cover bore.
2. After you install a **new** bushing in gearcase cover, line-ream the bushing to correct size. See BUSHING REAMING on page 3-48.

REAR INTAKE CAM GEAR BUSHING IN GEARCASE COVER.

1. See Figure 3-65. Rear intake cam gear bushing (15) must be installed in its gearcase cover (17) bore using an arbor press. You will need to orient the bushing in a specific position of rotation within the cover bore, and will need to drill a lubrication hole in the bushing, according to the following procedures.

Figure 3-69. Removing Bushing

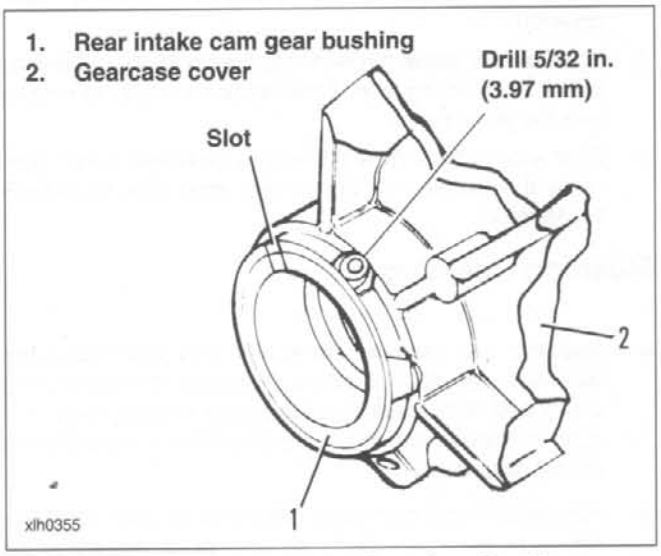


Figure 3-70. Rear Intake Cam Gear Bushing Installed in Gearcase Cover

2. See Figure 3-70. Position bushing (1) over bore of gearcase cover (2) with chamfered edge downward and slot upward. Align slot in bushing with slot in gearcase cover boss. Press bushing into cover bore until bushing is flush with cover boss.
3. Drill a 5/32 in. (3.97 mm) diameter hole through bushing using existing hole in gearcase cover as a guide.
4. After you install a **new** bushing in gearcase cover, line-ream the bushing to the correct size. See BUSHING REAMING on page 3-48.

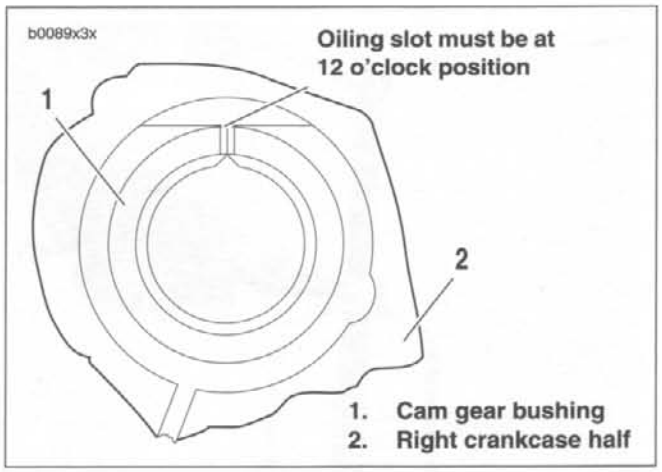


Figure 3-71. Cam Gear Bushing Installed in Crankcase

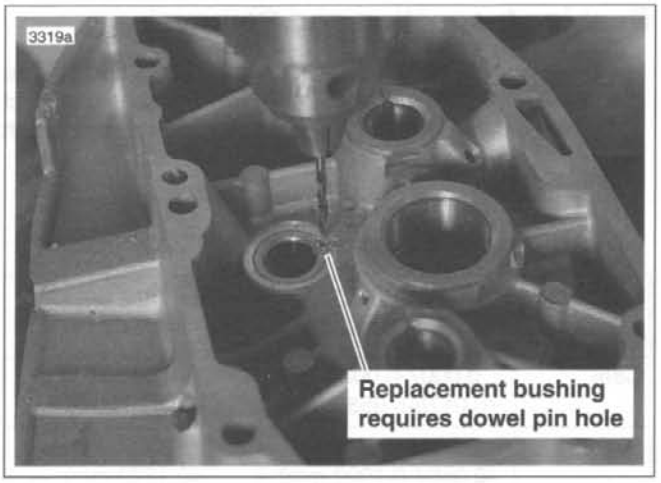


Figure 3-72. Drilling Dowel Pin Hole

PINION SHAFT BUSHING IN GEARCASE COVER

1. See Figure 3-65. Using an arbor press, install pinion shaft bushing (16) in its gearcase cover (17) so that bushing is flush with cover boss. There is no need to orient this particular bushing in any specific position of rotation within the gearcase cover bore.
2. Although the original pinion shaft bushing is not "pinned," the replacement bushing must be secured, from possible rotation within the cover bore, by installation of a dowel pin. See Figure 3-72. Drill a No. 31 hole, 0.281 in. (7.137 mm) deep, at top side of boss (side toward top of gearcase cover), centering the drill bit on the cover bore circle (hole is drilled half in bushing OD and half in cover bore ID).
3. Drive a **new** dowel pin no more than 0.20 in. (5.08 mm) below the bushing face. Carefully peen edges of hole to lock the pin in place.
4. After you install a **new** bushing in gearcase cover, line-ream the bushing to the correct size. See BUSHING REAMING.

Bushing Reaming

NOTE

- *Installing and reaming crankcase and gearcase cover bushings may alter the center distances between mating gears and may result in an increase in gear noise. For quiet-running gears, the gears should be matched to the center distances.*
- *Bushings in right crankcase half serve as pilots for reaming gearcase cover bushings and must, therefore, be reamed to size first.*
- *After reaming any bushing, check shaft fit in the bushing. It may be necessary to make a second pass with reamer to attain proper fit.*

CAM GEAR BUSHINGS IN RIGHT CRANKCASE HALF

1. Separate two halves of crankcase, if not already accomplished. Place right crankcase half on flat surface with gearcase side upward. Bushing to be reamed must be oriented as shown in Figure 3-71.
2. See Figure 3-73. Position CAMSHAFT BUSHING REAMER PILOT (Part No. HD-38871) onto gearcase side of crankcase half; upper right and lower left indexing holes in pilot must be placed over dowels in crankcase half. Insert two bolts (supplied with pilot) through two remaining holes in pilot, and into threaded holes of crankcase half. Tighten bolts securely.
3. Insert the 11/16 in. diameter reamer through pilot hole and into bushing while turning reamer clockwise. Continue turning reamer clockwise through bushing until smooth shank of reamer passes through hole in pilot.
4. Detach reamer from handle. Pull reamer out opposite side of crankcase half.
5. Thoroughly clean right crankcase half, removing all metal chips/shavings. Blow out all oil passages using compressed air.

CAM GEAR BUSHINGS (EXCEPT REAR INTAKE BUSHING) IN GEARCASE COVER

NOTE

Newly installed cam gear bushings in the gearcase cover must be line reamed, using the right crankcase half as a pilot for the reamer, to establish correct clearance and to ensure perfect alignment. If crankcase halves are not separated on your motorcycle, use a spare right crankcase half to perform the following line reaming procedures.

1. See Figure 3-65. Bushings (7, 8 and 14) to be reamed must be installed in gearcase cover (17) as described in BUSHING INSTALLATION on page 3-47. Attach gearcase cover to right crankcase half (10), which has been disassembled from left crankcase half, securing with a minimum of three mounting screws.

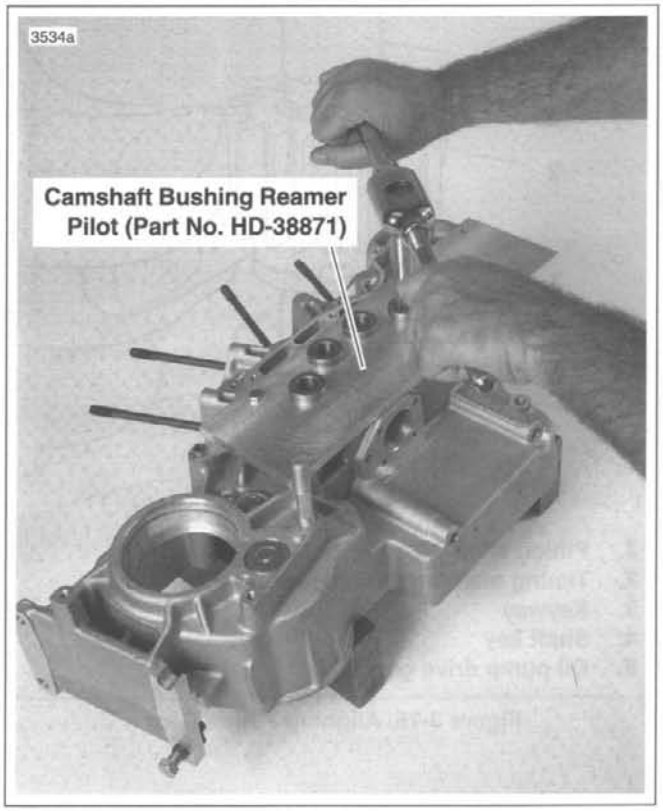


Figure 3-73. Reaming Cam Gear Bushing in Right Crankcase Half

2. Insert a standard 11/16 in. diameter reamer through the previously reamed cam gear bushing (13) in right crankcase half, which is in line with one of the bushings to be reamed in gearcase cover.

3. Turn reamer clockwise through bushing in cover until reamer bottoms. Then give reamer one complete clockwise turn to size the bushing. Continue turning reamer clockwise while extracting reamer from bushing.

4. Repeat Steps 2 and 3 for remaining two cam gear bushings (except rear intake bushing) in gearcase cover, if required.

5. Separate gearcase cover from right crankcase half. Inspect bushings for proper cam gear shaft fit. Repeat line reaming operation if necessary.

6. Thoroughly clean gearcase cover, removing all metal chips/shavings. Blow out all oil passages using compressed air.

REAR INTAKE CAM GEAR BUSHING IN GEARCASE COVER

NOTE

A newly installed rear intake cam gear bushing in the gearcase cover must be line reamed, using the right crankcase half as a pilot for the reamer, to establish correct clearance and to ensure perfect alignment. If crankcase halves are not separated on your motorcycle, use a spare right crankcase half to perform the following line reaming procedures.

1. See Figure 3-65. Rear intake cam gear bushing (15) must be installed in gearcase cover (17) as described in BUSHING INSTALLATION on page 3-47.

2. Identify the previously reamed rear intake cam gear bushing (13) in right crankcase half (10), which has been disassembled from left crankcase half. Insert the shank end of REAR INTAKE CAMSHAFT BUSHING REAMER (Part No. HD-94803-67) through gearcase side of this bushing.

3. With reamer inserted into bushing in right crankcase half, attach gearcase cover to right crankcase half, securing with a minimum of three mounting screws.

4. Turn reamer clockwise through bushing in gearcase cover until reamer bottoms. Then give reamer one complete clockwise turn to size the bushing. Continue turning reamer clockwise while extracting reamer from bushing.

5. Separate gearcase cover from right crankcase half. Inspect bushing for proper cam gear shaft fit. Repeat line reaming operation if necessary.

6. Thoroughly clean gearcase cover, removing all metal chips/shavings. Blow out all oil passages using compressed air.

PINION SHAFT BUSHING IN GEARCASE COVER

NOTE

*A **newly** installed pinion shaft bushing in the gearcase cover must be line reamed, using both the right crankcase half and Part No. HD-94812-87 as pilots for the reamer, to establish correct clearance and to ensure proper alignment. If crankcase halves are not separated on your motorcycle, use a spare right crankcase half to perform the following line reaming procedures.*

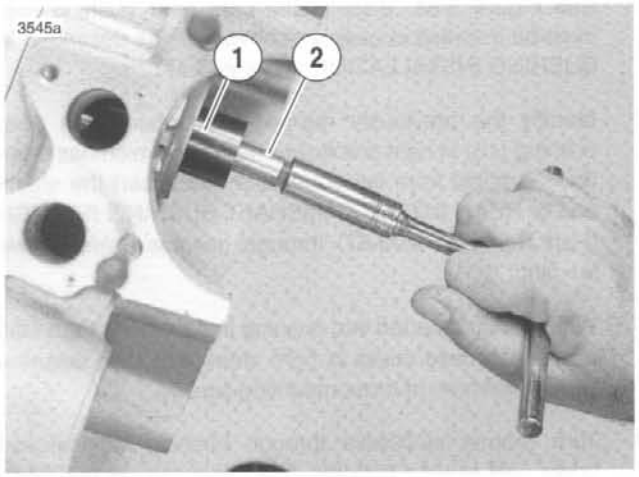
1. See Figure 3-65. Pinion shaft bushing (16) must be installed in gearcase cover (17) as described in BUSHING INSTALLATION on page 3-47. Attach gearcase cover to right crankcase half (10), which has been disassembled from left crankcase half, securing with a minimum of three mounting screws.

2. See Figure 3-74. Install PINION SHAFT BUSHING REAMER PILOT (Part No. HD-94812-87) into right crankcase roller race. Insert PINION SHAFT BUSHING REAMER (Part No. HD-94812-1) through the pilot.

3. Turn reamer clockwise through bushing in gearcase cover until reamer bottoms. Then give reamer one complete clockwise turn to size the bushing. Continue turning reamer clockwise while extracting reamer from bushing.

4. Separate gearcase cover from right crankcase half. Inspect bushing for proper pinion shaft fit. Repeat line reaming operation if necessary.

5. Remove pilot from right crankcase roller race. Thoroughly clean gearcase cover, removing all metal chips/shavings. Blow out all oil passages using compressed air.



1. **Pilot (Part No. HD-94812-87)**
2. **Reamer (Part No. HD-94812-1)**

Figure 3-74. Line Reaming Pinion Shaft Bushing

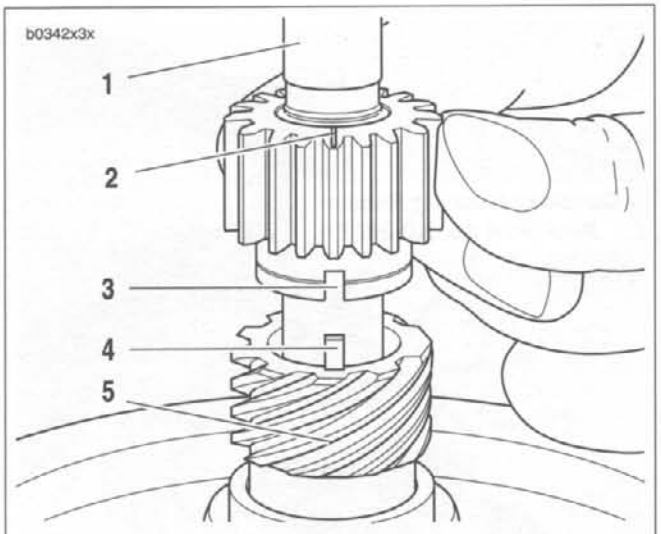
ASSEMBLY/INSTALLATION

1. See Figure 3-75. Install oil pump drive gear (5) and pinion gear on pinion shaft.
   a. Slide oil pump gear drive gear (5) over pinion shaft (1). Drive gear must align with shaft key (4).
   b. Align keyway (3) in ID of pinion gear with shaft key (4).
   c. Slide pinion gear over shaft key (4) and against oil pump drive gear (5).
2. See Figure 3-65. Install nut (11).
   a. Clean threads on pinion shaft and nut.
   b. Apply several drops of LOCTITE THREADLOCKER 262 (red) to threads of nut.
   c. See Figure 3-76. Install CRANKSHAFT LOCKING TOOL (Part No. HD-41506) over pinion shaft.
   d. Tighten nut to 35-45 ft-lbs (47.5-61.0 Nm).
3. Liberally apply engine oil to bushings, shafts, and gears. Install all cam gears into bushings of right crankcase half, properly aligning timing marks of cam gears and pinion gear. See Figure 3-68.

NOTE

Because of the larger diameter additional gear (which meshes with the pinion gear) on the outboard end of the rear intake (15-2) cam gear, the rear exhaust (15-1) and front intake (15-3) cam gears must both be installed before the rear intake (15-2) cam gear is installed.

4. See Figure 3-65. Install a **new** seal (6) and **new** dry gearcover gasket (9) on gearcase cover (17).



1. **Pinion shaft**
2. **Timing mark on pinion gear**
3. **Keyway**
4. **Shaft key**
5. **Oil pump drive gear**

Figure 3-75. Aligning Pinion Gear

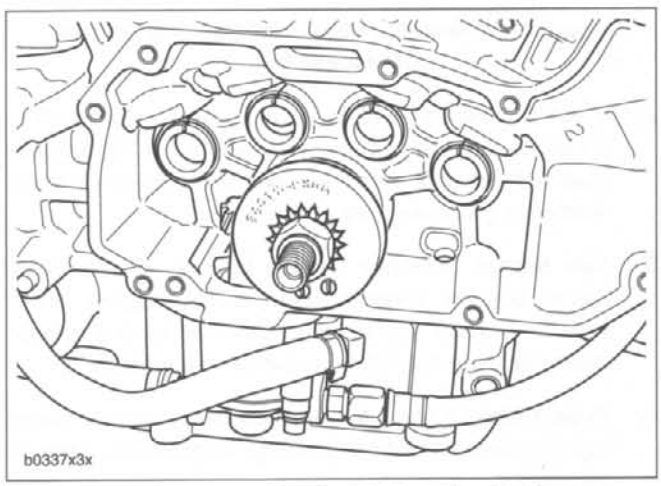


Figure 3-76. Crankshaft Locking Tool

5. Install gearcase cover over all gears and onto right crankcase half (10). Secure cover to crankcase half with 11 socket head screws. Tighten screws evenly to 80-110 **in-lbs** (9.0-12.4 Nm). Use torque sequence shown in Figure 3-77.
6. See Figure 3-78. Check cam gear end play for each cam gear as follows:
   a. Turn engine over until lobe of cam gear being checked is pointing toward its respective tappet guide hole.
   b. Gently pry the cam gear toward the gearcase cover using a flat blade screwdriver.
   c. Measure gap between bushing (in crankcase half) and cam gear shaft thrust face (shoulder) using a feeler gauge. This is cam gear end play.
   d. Compare cam gear end play measurements with the SERVICE WEAR LIMITS. Make repairs as required if end play does not meet specifications.
7. Install valve tappets and push rods. See 3.15 VALVE TAPPETS (1999 models).
8. Install cam position sensor in gearcase cover. See 4.29 CAM POSITION SENSOR AND ROTOR.
9. Install any components removed to gain access to gearcase (i.e. exhaust system components, air cleaner, etc.).
10. Check engine timing. See 1.23 IGNITION TIMING

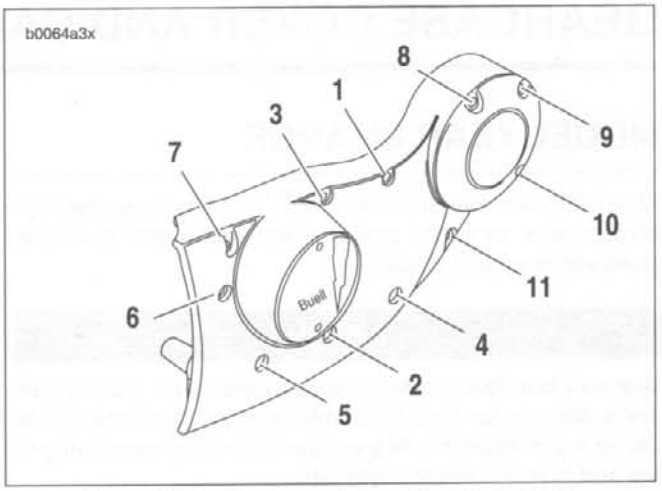


Figure 3-77. Gearcase Cover Mounting Screw Torque Sequence

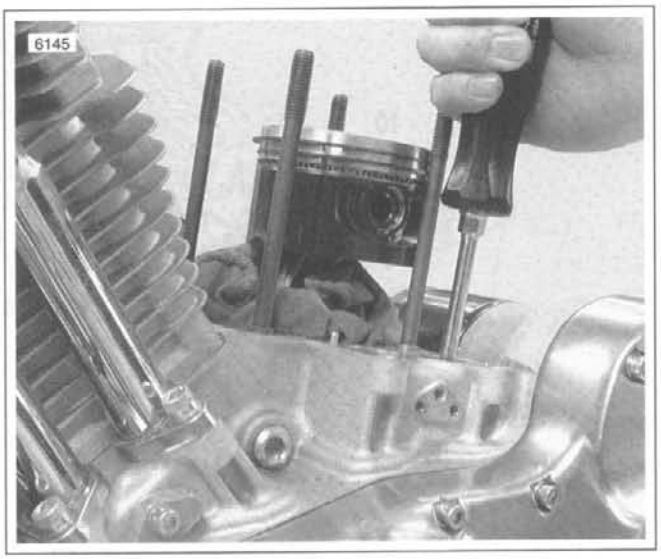


Figure 3-78. Checking Cam Gear End Play

GEARCASE COVER AND CAM GEARS (2000 MODELS) 3.18

MODEL YEAR CHANGE

All 2000 Model Year Thunderstorm™ engines have new high contact ratio drive and pinion gears and a new gearcase, gearcase cover and gasket.

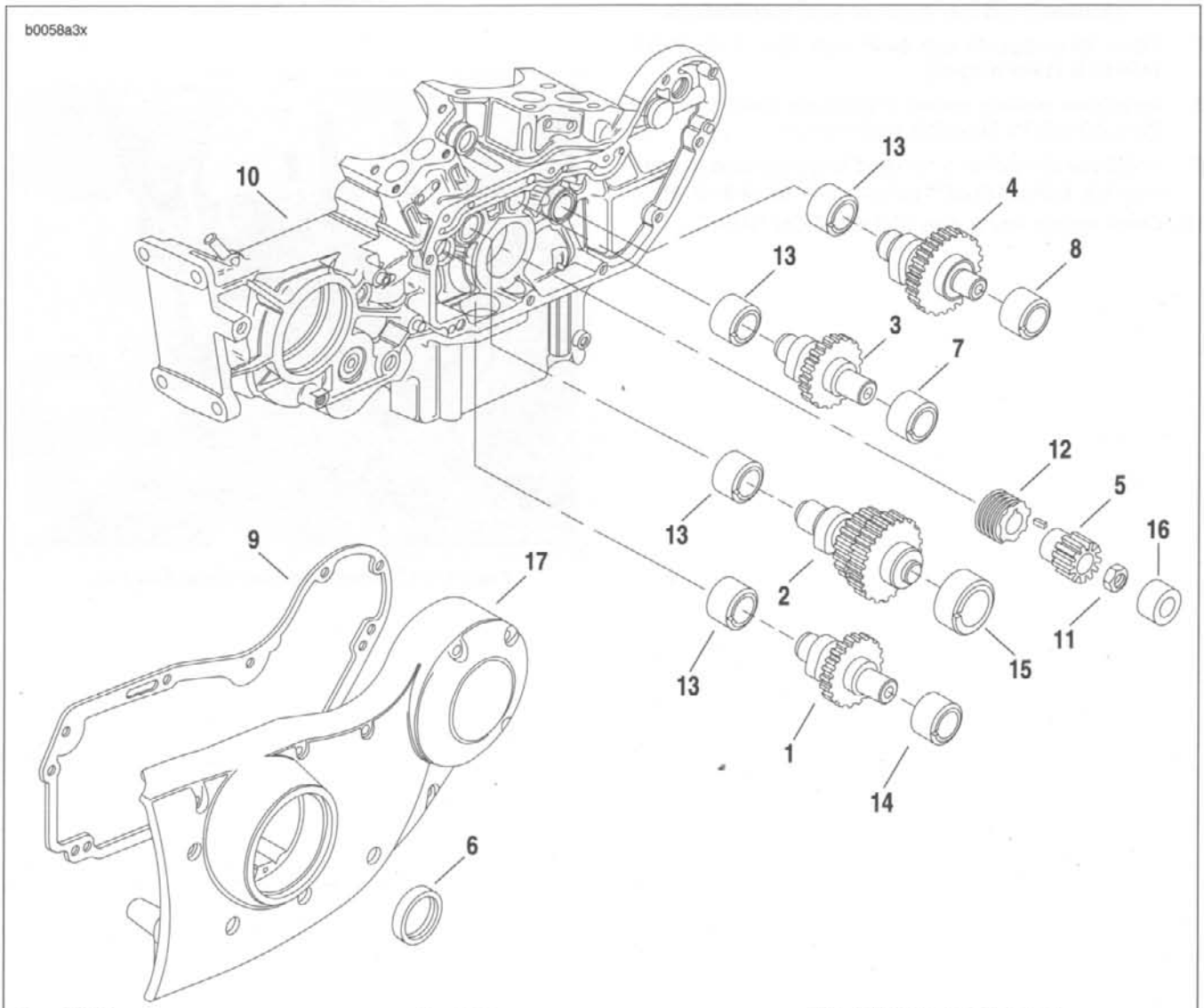
CAUTION

Use only the 2000 model year gearcase cover gasket (see parts catalog for Part No.) with the new gearcase cover. Using a previous model year gasket will obstruct oil galley and result in engine damage.

GENERAL

Read the complete gearcase section carefully before you begin any service work.

For the gearcase components to operate at their optimum, all components must be properly fitted and matched. Changing one component can affect many others. It is important to know and understand all inspection procedures and how components interact.



1. Rear exhaust cam gear
2. Rear intake cam gear
3. Front intake cam gear
4. Front exhaust cam gear
5. Pinion gear
6. Seal
7. Front intake cam gear bushing
8. Front exhaust cam gear bushing
9. Gearcase cover gasket
10. Right crankcase half
11. Nut
12. Oil pump drive gear
13. Cam gear bushing (4)
14. Rear exhaust cam gear bushing
15. Rear intake cam gear bushing
16. Pinion shaft bushing
17. Gearcase cover

Figure 3-79. Gearcase and Valve Train Components

REMOVAL/DISASSEMBLY

1. See Figure 3-79. Thoroughly clean area around gearcase cover (17) and tappets. Blow loose dirt from crankcase with compressed air.
2. Remove any parts that will interfere with gearcase disassembly (i.e., exhaust header, air cleaner, etc.).
3. Remove push rods. See 3.5 CYLINDER HEAD.
4. Remove hydraulic lifters. See 3.16 HYDRAULIC LIFTERS (2000 models).
5. Check for minimum cam gear end play. Record readings.
6. Remove cam position sensor from gearcase cover. See 4.29 CAM POSITION SENSOR AND ROTOR.
7. Place a pan under gearcase to collect oil. Remove cover screws. Carefully remove gearcase cover. Discard old gasket (9).

NOTE

If cover does not come loose on removal of screws, tap lightly with a plastic hammer. Never pry cover off.

8. Remove cam gears (1, 2, 3 and 4). Carefully mark each component to ensure correct installation.

NOTE

Nut (11) is secured by LOCTITE THREADLOCKER 262 (red) on the nut threads.

9. Remove nut (11). Slide pinion gear (5) and oil pump drive gear (12) off pinion shaft.

CLEANING AND INSPECTION

1. Thoroughly clean gearcase compartment, gearcase cover and gears in solvent to remove oil and carbon deposits.
2. Blow out all cover oil passages and bushings with compressed air.
3. Clean old gasket material from gearcase and cover faces with cleaning solvent.

Cam and Pinion Gear Identification, Inspection, and Selection

See Figure 3-80. Cam lobes are stamped with the number "15" followed by a number (1, 2, 3 or 4). The number "15" indicates model year application; the number identifies the cam location/function:

15-1 = rear exhaust
15-2 = rear intake
15-3 = front intake
15-4 = front exhaust

Use only "15" cams on 1998 models.

See Figure 3-81. Measure the gear diameter with a micrometer over 0.108 in. (2.743 mm) diameter gauge pins on opposite sides of the gear. The pins are of the proper size to fit between the contacting surfaces of the gear teeth. Gear diameter should be measured in at least two places 90° apart. Use GAUGE PIN SET (Part No. HD-38361) when measuring pinion and cam gear sizes.

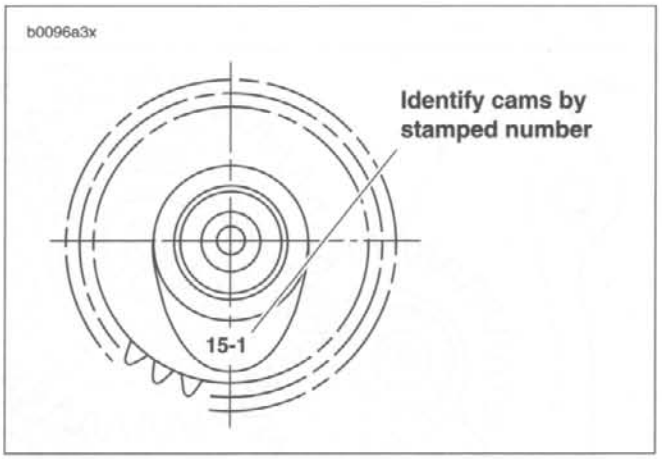


Figure 3-80. Cam Identification

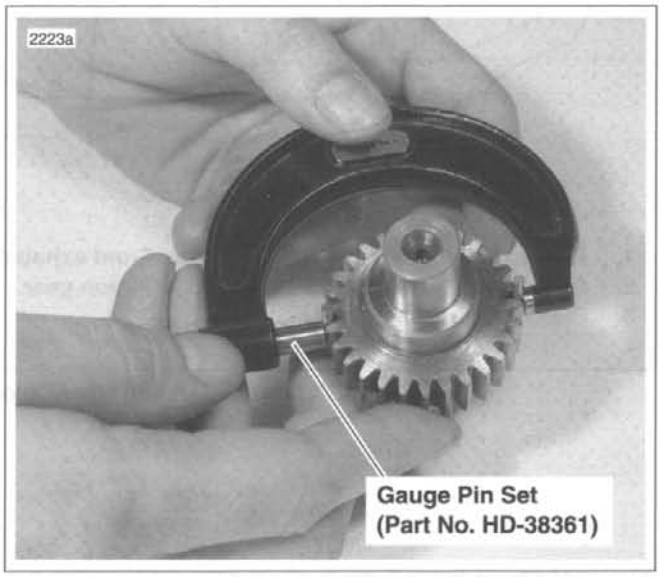


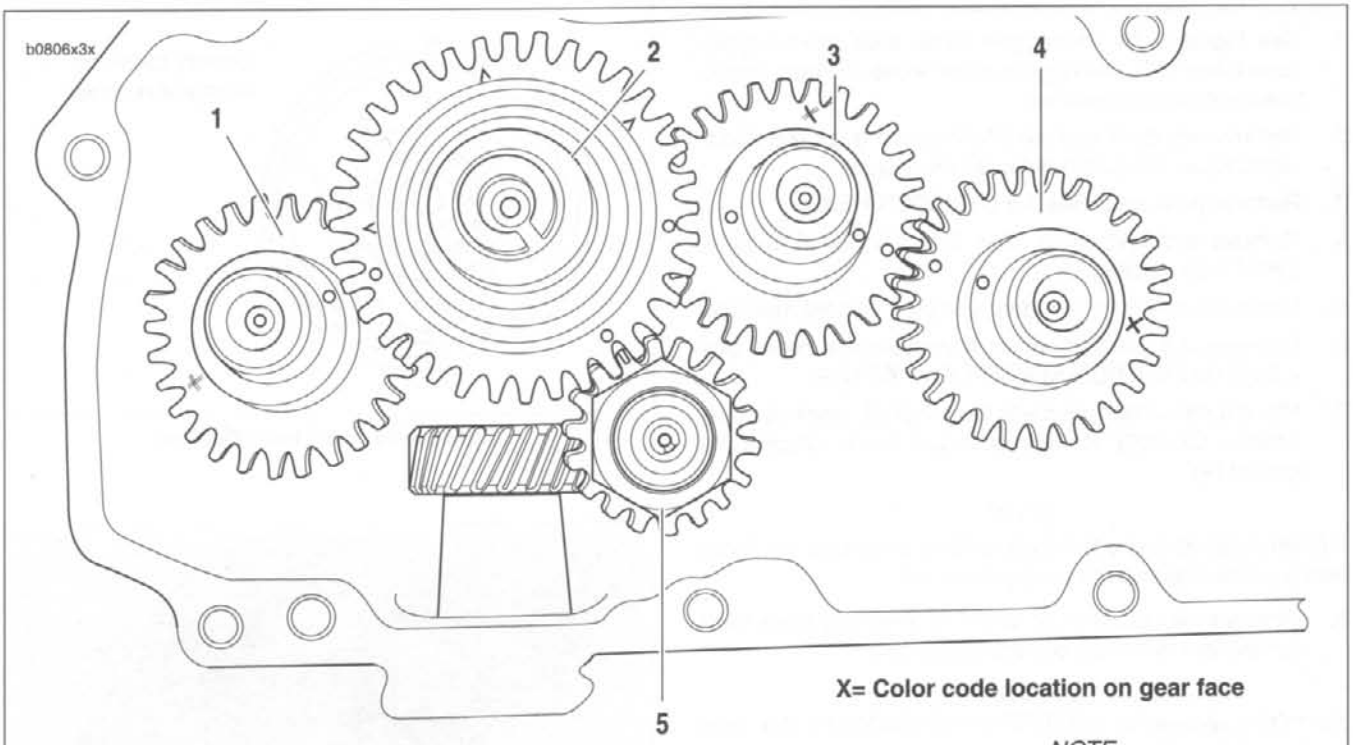
Figure 3-81. Measuring Gear Size

Cam and pinion gears are individually selected for each specific gear cover through sophisticated computer-aided measuring techniques in a controlled environment. Each gear is assigned an individual color code based on its diameter (measured with gauge pins). When cam and/or pinion gears are replaced, always use the same color code as found on gears being replaced to ensure that the gear operation remains as quiet as possible. For location of cam and pinion gear color codes, see Figure 3-82.

NOTE

On flywheel pinion shaft, a paint dot is located on the shaft perimeter near the centerline of the keyway. This dot identifies the pinion shaft inner race size. Do not use this dot to select pinion gear size.

See Table 3-12. Compare the previously measured diameter of each gear with the specifications (listed in inches) shown in the table to determine amount of wear on gear teeth.



1. **Rear exhaust cam gear (15-1)**
2. **Rear intake cam gear (15-2)**
3. **Front intake cam gear (15-3)**
4. **Front exhaust cam gear (15-4)**
5. **Pinion gear**

NOTE

Though not depicted, Rear Intake Cam Gear has 46 teeth and Pinion Gear has 23 teeth.

Figure 3-82. Cam and Pinion Gear Color Code Location and Timing Mark Indexing

NOTE

Prior to changing any cam gears, check gear shaft fit within corresponding bushings. Worn bushings can cause excessive backlash.

Table 3-12. Cam and Pinion Gear Color Code and Diameter

GEAR NO. & POSITION	1	2 INBOARD	2 OUT-BOARD	3	4	5
COLOR CODE (1 paint dot)	Rear Exhaust	Rear Intake	Rear Intake	Front Intake	Front Exhaust	Pinion
RED	1.9015-1.9019 (48.298-48.308)	1.9025-1.9029 (48.323-48.333)	2.4031-2.4035 (61.038-61.049)	1.9015-1.9019 (48.298-48.308)	1.9025-1.9029 (48.323-48.333)	
WHITE	1.9020-1.9024 (48.310-48.321)	1.9020-1.9024 (48.310-48.321)	2.4036-2.4040 (61.051-61.061)	1.9020-1.9024 (48.310-48.321)	1.9020-1.9024 (48.310-48.321)	
GREEN	1.9025-1.9029 (48.323-48.333)	1.9015-1.9019 (48.298-48.308)	2.4041-2.4045 (61.064-61.074)	1.9025-1.9029 (48.323-48.333)	1.9015-1.9019 (48.298-48.308)	

Bushing Inspection and Removal

1. See Figure 3-79. Bushings (7, 8, 13, 14, 15 and 16) are press fit in gearcase cover (17) and crankcase. Inspect each bushing against its corresponding cam gear shaft or pinion gear shaft. See Table 3-13.

Table 3-13. Gear Shaft Specifications

GEAR SHAFT	CORRECT CLEARANCE	SERVICE WEAR LIMIT
Cam	0.0007-0.0022 in. (0.0178-0.0559 mm)	0.003 in. (0.076 mm)
Pinion	0.0023-0.0043 in. (0.0584-0.1092 mm)	0.0050 in. (0.1270 mm)

2. See Figure 3-83. Use a BUSHING AND BEARING PULLER (Part No. HD-95760-69A) to remove bushings from gearcase cover and crankcase.

Bushing Installation

NOTE

Installing and reaming crankcase and gearcase cover bushings may alter the center distances between mating gears and may result in an increase in gear noise. For quiet-running gears, the gears should be matched to the center distances.

CAM GEAR BUSHINGS IN RIGHT CRANKCASE HALF

1. See Figure 3-85. Each cam gear bushing (1), to be installed in right crankcase half (2), must be positioned in crankcase bore with its oiling slot at exact top of bore (12 o'clock position).
2. Using an arbor press, install each bushing in its crankcase bore so that bushing shoulder contacts crankcase boss.
3. After you install a **new** bushing in right crankcase half, ream the bushing to correct size. See BUSHING REAMING.

CAM GEAR BUSHINGS (EXCEPT REAR INTAKE BUSHING) IN GEARCASE COVER

1. See Figure 3-79. Using an arbor press, install each bushing (7, 8 and 14) in its gearcase cover (17) bore so that bushing shoulder contacts cover boss. Orient each bushing so the oiling slot is at the 9 o'clock position within the gearcase cover bore.
2. After you install a **new** bushing in gearcase cover, line-ream the bushing to correct size. See BUSHING REAMING.

REAR INTAKE CAM GEAR BUSHING IN GEARCASE COVER.

1. See Figure 3-79. Rear intake cam gear bushing (15) must be installed in its gearcase cover (17) bore using an arbor press. You will need to orient the bushing in a specific position of rotation within the cover bore, and will need to drill a lubrication hole in the bushing, according to the following procedures.

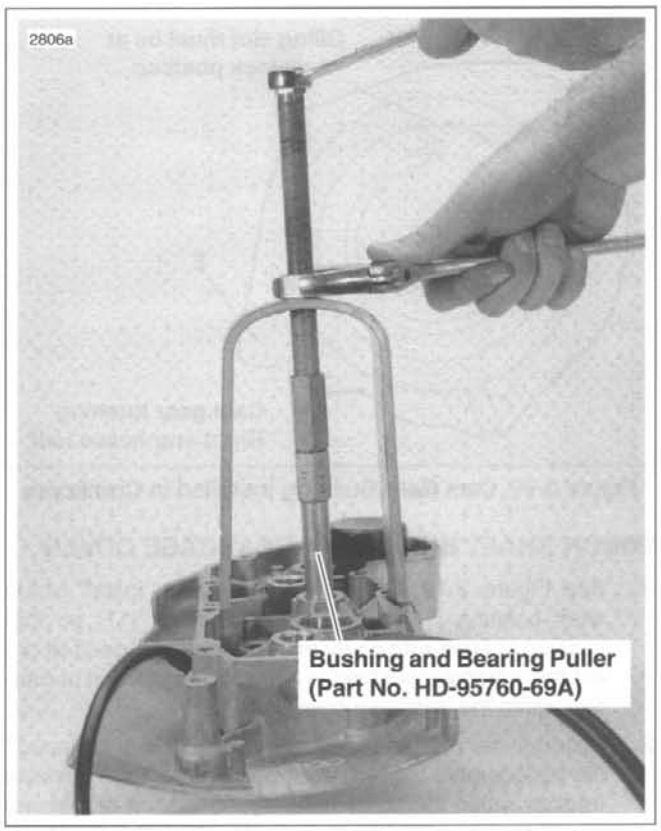


Figure 3-83. Removing Bushing

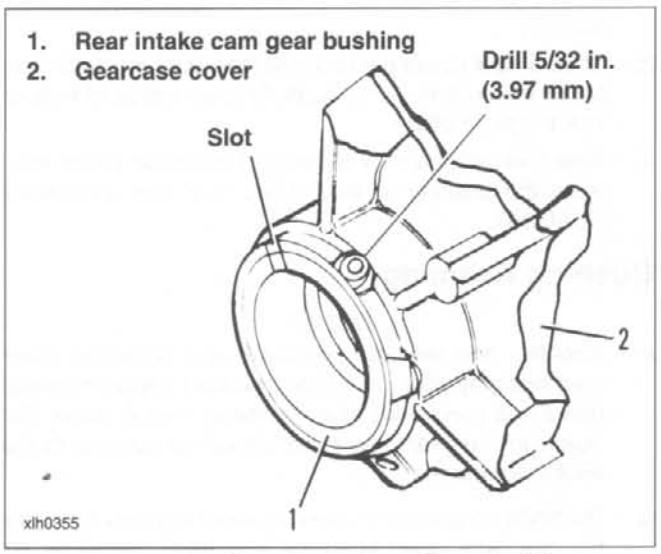


Figure 3-84. Rear Intake Cam Gear Bushing Installed in Gearcase Cover

2. See Figure 3-84. Position bushing (1) over bore of gearcase cover (2) with chamfered edge downward and slot upward. Align slot in bushing with slot in gearcase cover boss. Press bushing into cover bore until bushing is flush with cover boss.
3. Drill a 5/32 in. (3.97 mm) diameter hole through bushing using existing hole in gearcase cover as a guide.
4. After you install a **new** bushing in gearcase cover, line-ream the bushing to the correct size. See BUSHING REAMING.

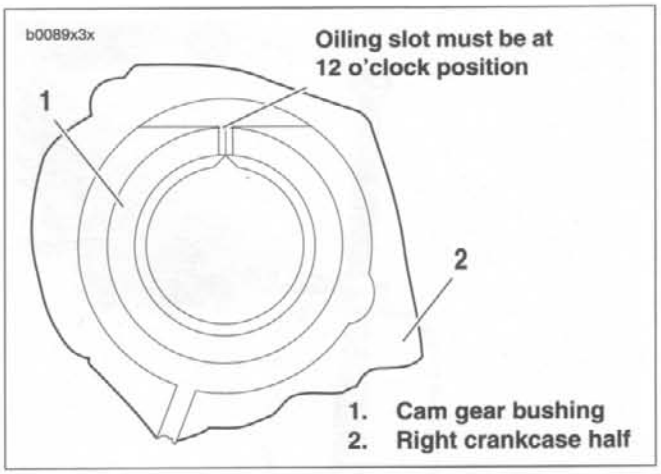


Figure 3-85. Cam Gear Bushing Installed in Crankcase

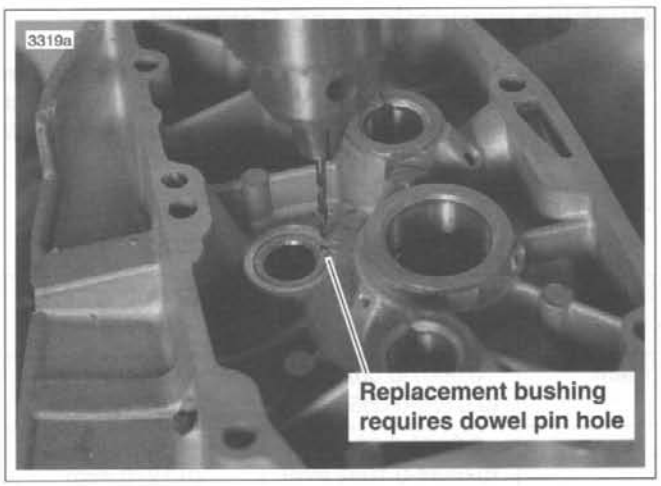


Figure 3-86. Drilling Dowel Pin Hole

PINION SHAFT BUSHING IN GEARCASE COVER

1. See Figure 3-79. Using an arbor press, install pinion shaft bushing (16) in its gearcase cover (17) so that bushing is flush with cover boss. There is no need to orient this particular bushing in any specific position of rotation within the gearcase cover bore.
2. Although the original pinion shaft bushing is not "pinned," the replacement bushing must be secured, from possible rotation within the cover bore, by installation of a dowel pin. See Figure 3-86. Drill a No. 31 hole, 0.281 in. (7.137 mm) deep, at top side of boss (side toward top of gearcase cover), centering the drill bit on the cover bore circle (hole is drilled half in bushing OD and half in cover bore ID).
3. Drive a **new** dowel pin no more than 0.20 in. (5.08 mm) below the bushing face. Carefully peen edges of hole to lock the pin in place.
4. After you install a **new** bushing in gearcase cover, line-ream the bushing to the correct size. See BUSHING REAMING.

Bushing Reaming

NOTE

- *Installing and reaming crankcase and gearcase cover bushings may alter the center distances between mating gears and may result in an increase in gear noise. For quiet-running gears, the gears should be matched to the center distances.*
- *Bushings in right crankcase half serve as pilots for reaming gearcase cover bushings and must, therefore, be reamed to size first.*
- *After reaming any bushing, check shaft fit in the bushing. It may be necessary to make a second pass with reamer to attain proper fit.*

CAM GEAR BUSHINGS IN RIGHT CRANKCASE HALF

1. Separate two halves of crankcase, if not already accomplished. Place right crankcase half on flat surface with gearcase side upward. Bushing to be reamed must be oriented as shown in Figure 3-85.
2. See Figure 3-87. Position CAMSHAFT BUSHING REAMER PILOT (Part No. HD-38871) onto gearcase side of crankcase half; upper right and lower left indexing holes in pilot must be placed over dowels in crankcase half. Insert two bolts (supplied with pilot) through two remaining holes in pilot, and into threaded holes of crankcase half. Tighten bolts securely.
3. Insert the 11/16 in. diameter reamer through pilot hole and into bushing while turning reamer clockwise. Continue turning reamer clockwise through bushing until smooth shank of reamer passes through hole in pilot.
4. Detach reamer from handle. Pull reamer out opposite side of crankcase half.
5. Thoroughly clean right crankcase half, removing all metal chips/shavings. Blow out all oil passages using compressed air.

CAM GEAR BUSHINGS (EXCEPT REAR INTAKE BUSHING) IN GEARCASE COVER

NOTE

Newly installed cam gear bushings in the gearcase cover must be line reamed, using the right crankcase half as a pilot for the reamer, to establish correct clearance and to ensure perfect alignment. If crankcase halves are not separated on your motorcycle, use a spare right crankcase half to perform the following line reaming procedures.

1. See Figure 3-79. Bushings (7, 8 and 14) to be reamed must be installed in gearcase cover (17) as described in BUSHING INSTALLATION. Attach gearcase cover to right crankcase half (10), which has been disassembled from left crankcase half, securing with a minimum of three mounting screws.

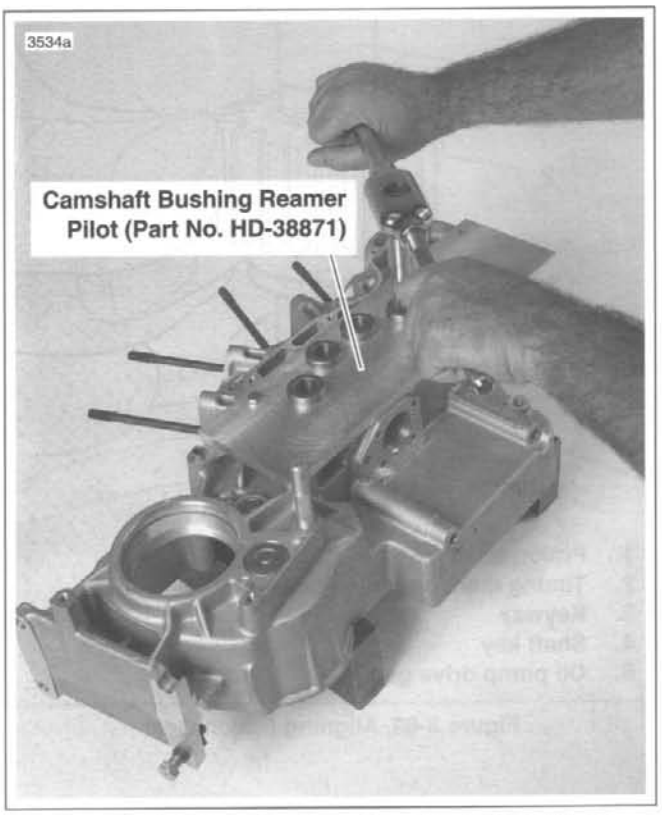


Figure 3-87. Reaming Cam Gear Bushing in Right Crankcase Half

2. Insert a standard 11/16 in. diameter reamer through the previously reamed cam gear bushing (13) in right crankcase half, which is in line with one of the bushings to be reamed in gearcase cover.

3. Turn reamer clockwise through bushing in cover until reamer bottoms. Then give reamer one complete clockwise turn to size the bushing. Continue turning reamer clockwise while extracting reamer from bushing.

4. Repeat Steps 2 and 3 for remaining two cam gear bushings (except rear intake bushing) in gearcase cover, if required.

5. Separate gearcase cover from right crankcase half. Inspect bushings for proper cam gear shaft fit. Repeat line reaming operation if necessary.

6. Thoroughly clean gearcase cover, removing all metal chips/shavings. Blow out all oil passages using compressed air.

REAR INTAKE CAM GEAR BUSHING IN GEARCASE COVER

NOTE

A newly installed rear intake cam gear bushing in the gearcase cover must be line reamed, using the right crankcase half as a pilot for the reamer, to establish correct clearance and to ensure perfect alignment. If crankcase halves are not separated on your motorcycle, use a spare right crankcase half to perform the following line reaming procedures.

1. See Figure 3-79. Rear intake cam gear bushing (15) must be installed in gearcase cover (17) as described in BUSHING INSTALLATION.

2. Identify the previously reamed rear intake cam gear bushing (13) in right crankcase half (10), which has been disassembled from left crankcase half. Insert the shank end of REAR INTAKE CAMSHAFT BUSHING REAMER (Part No. HD-94803-67) through gearcase side of this bushing.

3. With reamer inserted into bushing in right crankcase half, attach gearcase cover to right crankcase half, securing with a minimum of three mounting screws.

4. Turn reamer clockwise through bushing in gearcase cover until reamer bottoms. Then give reamer one complete clockwise turn to size the bushing. Continue turning reamer clockwise while extracting reamer from bushing.

5. Separate gearcase cover from right crankcase half. Inspect bushing for proper cam gear shaft fit. Repeat line reaming operation if necessary.

6. Thoroughly clean gearcase cover, removing all metal chips/shavings. Blow out all oil passages using compressed air.

PINION SHAFT BUSHING IN GEARCASE COVER

NOTE

*A **newly** installed pinion shaft bushing in the gearcase cover must be line reamed, using both the right crankcase half and Part No. HD-94812-87 as pilots for the reamer, to establish correct clearance and to ensure proper alignment. If crankcase halves are not separated on your motorcycle, use a spare right crankcase half to perform the following line reaming procedures.*

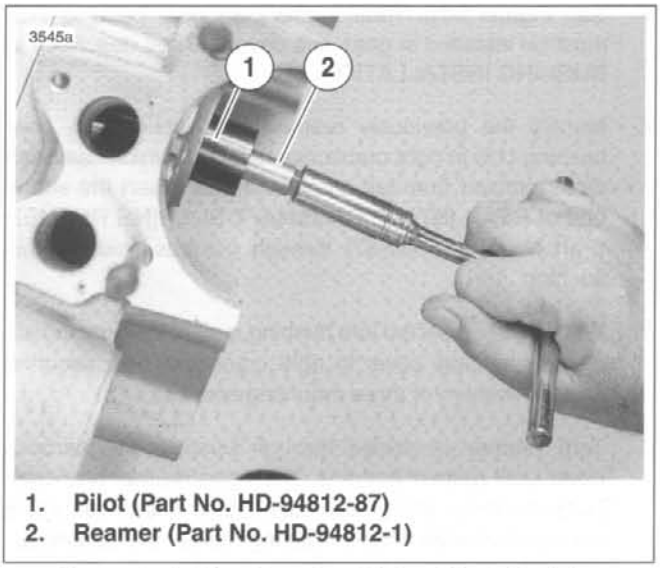
1. See Figure 3-79. Pinion shaft bushing (16) must be installed in gearcase cover (17) as described in BUSHING INSTALLATION. Attach gearcase cover to right crankcase half (10), which has been disassembled from left crankcase half, securing with a minimum of three mounting screws.

2. See Figure 3-88. Install PINION SHAFT BUSHING REAMER PILOT (Part No. HD-94812-87) into right crankcase roller race. Insert PINION SHAFT BUSHING REAMER (Part No. HD-94812-1) through the pilot.

3. Turn reamer clockwise through bushing in gearcase cover until reamer bottoms. Then give reamer one complete clockwise turn to size the bushing. Continue turning reamer clockwise while extracting reamer from bushing.

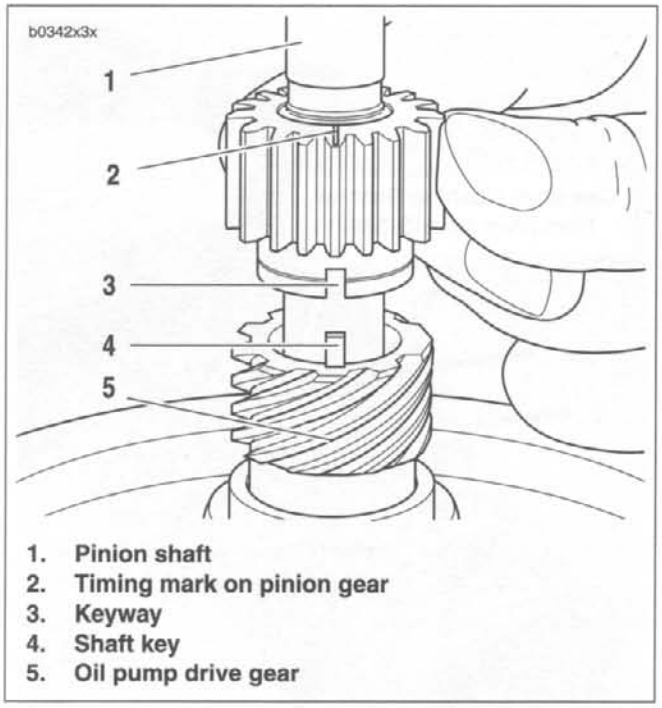
4. Separate gearcase cover from right crankcase half. Inspect bushing for proper pinion shaft fit. Repeat line reaming operation if necessary.

5. Remove pilot from right crankcase roller race. Thoroughly clean gearcase cover, removing all metal chips/shavings. Blow out all oil passages using compressed air.



1. **Pilot (Part No. HD-94812-87)**
2. **Reamer (Part No. HD-94812-1)**

Figure 3-88. Line Reaming Pinion Shaft Bushing



1. **Pinion shaft**
2. **Timing mark on pinion gear**
3. **Keyway**
4. **Shaft key**
5. **Oil pump drive gear**

Figure 3-89. Aligning Pinion Gear

ASSEMBLY/INSTALLATION

1. See Figure 3-89. Install oil pump drive gear (5) and pinion gear on pinion shaft.
   a. Slide oil pump gear drive gear (5) over pinion shaft (1). Drive gear must align with shaft key (4).
   b. Align keyway (3) in ID of pinion gear with shaft key (4).
   c. Slide pinion gear over shaft key (4) and against oil pump drive gear (5).
2. See Figure 3-79. Install nut (11).
   a. Clean threads on pinion shaft and nut.
   b. See Figure 3-90. Install CRANKSHAFT LOCKING TOOL (Part No. HD-43984) to gearcase with "Side A" facing out, over pinion shaft, with two screws.
   c. Apply several drops of LOCTITE THREADLOCKER 262 (red) to threads of nut.
   d. Install nut to pinion shaft. Tighten nut to 35-45 ft-lbs (47.5-61.0 Nm).
3. Liberally apply engine oil to bushings, shafts, and gears. Install all cam gears into bushings of right crankcase half, properly aligning timing marks of cam gears and pinion gear. See Figure 3-82.

NOTE

Because of the larger diameter additional gear (which meshes with the pinion gear) on the outboard end of the rear intake (15-2) cam gear, the rear exhaust (15-1) and front intake (15-3) cam gears must both be installed before the rear intake (15-2) cam gear is installed.

CAUTION

Use only the 2000 model year gearcase cover gasket (see parts catalog for Part No.) with the new gearcase cover. Using previous gasket will obstruct oil galley and result in engine damage.

4. See Figure 3-79. Install a **new** seal (6) and **new** dry gearcover gasket (9) on gearcase cover (17).

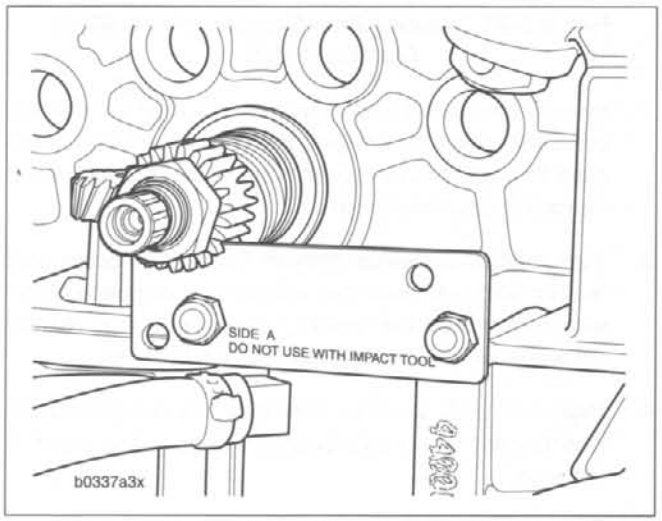


Figure 3-90. Crankshaft Locking Tool (HD-43984)

5. Install gearcase cover over all gears and onto right crankcase half (10). Secure cover to crankcase half with 11 socket head screws. Tighten screws evenly to 80-110 **in-lbs** (9.0-12.4 Nm). Use torque sequence shown in Figure 3-91.
6. See Figure 3-92. Check cam gear end play for each cam gear as follows:
   a. Turn engine over until lobe of cam gear being checked is pointing toward its respective tappet guide hole.
   b. Gently pry the cam gear toward the gearcase cover using a flat blade screwdriver.
   c. Measure gap between bushing (in crankcase half) and cam gear shaft thrust face (shoulder) using a feeler gauge. This is cam gear end play.
   d. Compare cam gear end play measurements with the SERVICE WEAR LIMITS. Make repairs as required if end play does not meet specifications.
7. Install hydraulic lifters and push rods. See 3.16 HYDRAULIC LIFTERS (2000 models).
8. Install cam position sensor in gearcase cover. See 4.29 CAM POSITION SENSOR AND ROTOR.
9. Install any components removed to gain access to gearcase (i.e. exhaust system components, air cleaner, etc.).

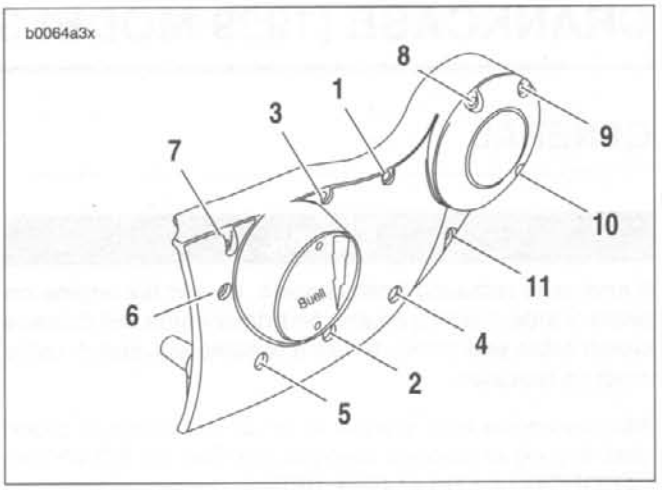


Figure 3-91. Gearcase Cover Mounting Screw Torque Sequence

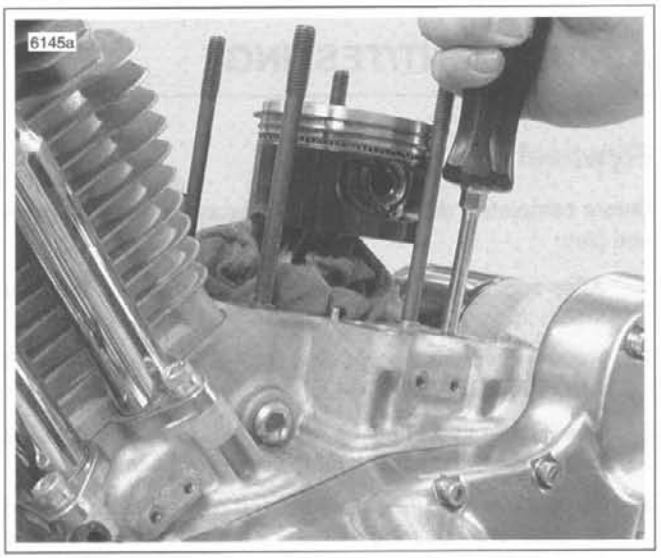


Figure 3-92. Checking Cam Gear End Play

GENERAL

CAUTION

If engine is removed from chassis, do not lay engine on primary side. Placing engine on primary side will damage clutch cable end fitting. If fitting is damaged, clutch cable must be replaced.

Remove engine from chassis to repair rod bearings, pinion shaft bearing or sprocket shaft bearing. See 3.3 STRIPPING MOTORCYCLE FOR ENGINE REPAIR.

It is recommended procedure to overhaul engine if removed. This includes inspecting and repairing cylinder heads, cylinders, gearcase and transmission.

ADJUSTMENT/TESTING

Flywheel End Play

Before completely disassembling crankcases, check flywheel end play.

1. After engine has been removed from chassis, securely fasten it to a stand or workbench.
2. Remove gearcase cover. See 3.17 GEARCASE COVER AND CAM GEARS (1999 models).
3. See Figure 3-93. Attach a dial indicator to gear side crankcase with indicator stem on end of gearshaft.
4. To obtain an accurate flywheel end play reading, preload sprocket shaft bearings. Create a suitable tool by welding two handles to an old engine sprocket nut. Install the nut and sprocket. Tighten to 190-210 ft-lbs (257.6-284.7 Nm).
5. Check flywheel end play.
   a. Rotate and **push** on sprocket shaft while reading dial indicator.
   b. Then rotate and **pull** on sprocket shaft while reading dial indicator.
   c. Replace bearing inner spacer (item 6, Figure 3-96.) if difference (end play) in indicator readings is not 0.001-0.005 in. (0.025-0.127 mm). Choose spacer from Table 3-14.

NOTE

Use a thinner spacer for less end play; use a thicker spacer for more end play.

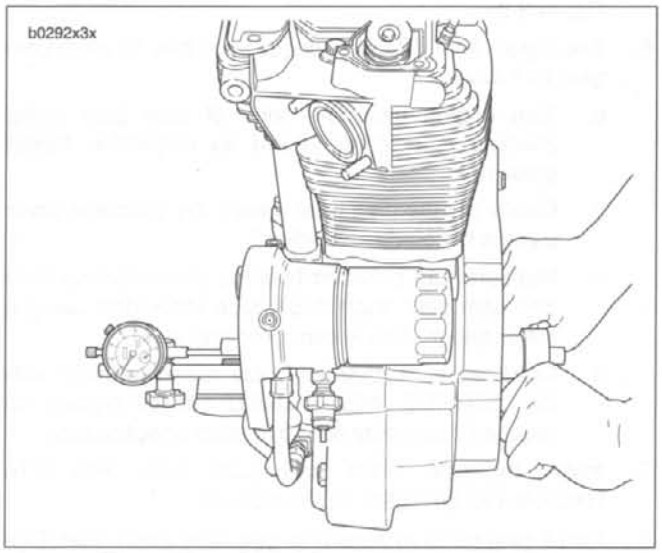


Figure 3-93. Checking Flywheel End Play

Table 3-14. Flywheel End Play Spacers

PART NUMBER	THICKNESS	
	IN.	MM
9155	0.0975-0.0985	2.4765-2.5019
9142	0.0995 - 0.1005	2.5273-2.5527
9143	0.1015-0.1025	2.5781-2.6035
9144	0.1035 - 0.1045	2.6289-2.6543
9145	0.1055 - 0.1065	2.6797-2.7051
9146	0.1075 - 0.1085	2.7305-2.7559
9147	0.1095 - 0.1105	2.7813-2.8067
9148	0.1115 - 0.1125	2.8321-2.8575
9149	0.1135 - 0.1145	2.8829-2.9083

DISASSEMBLY

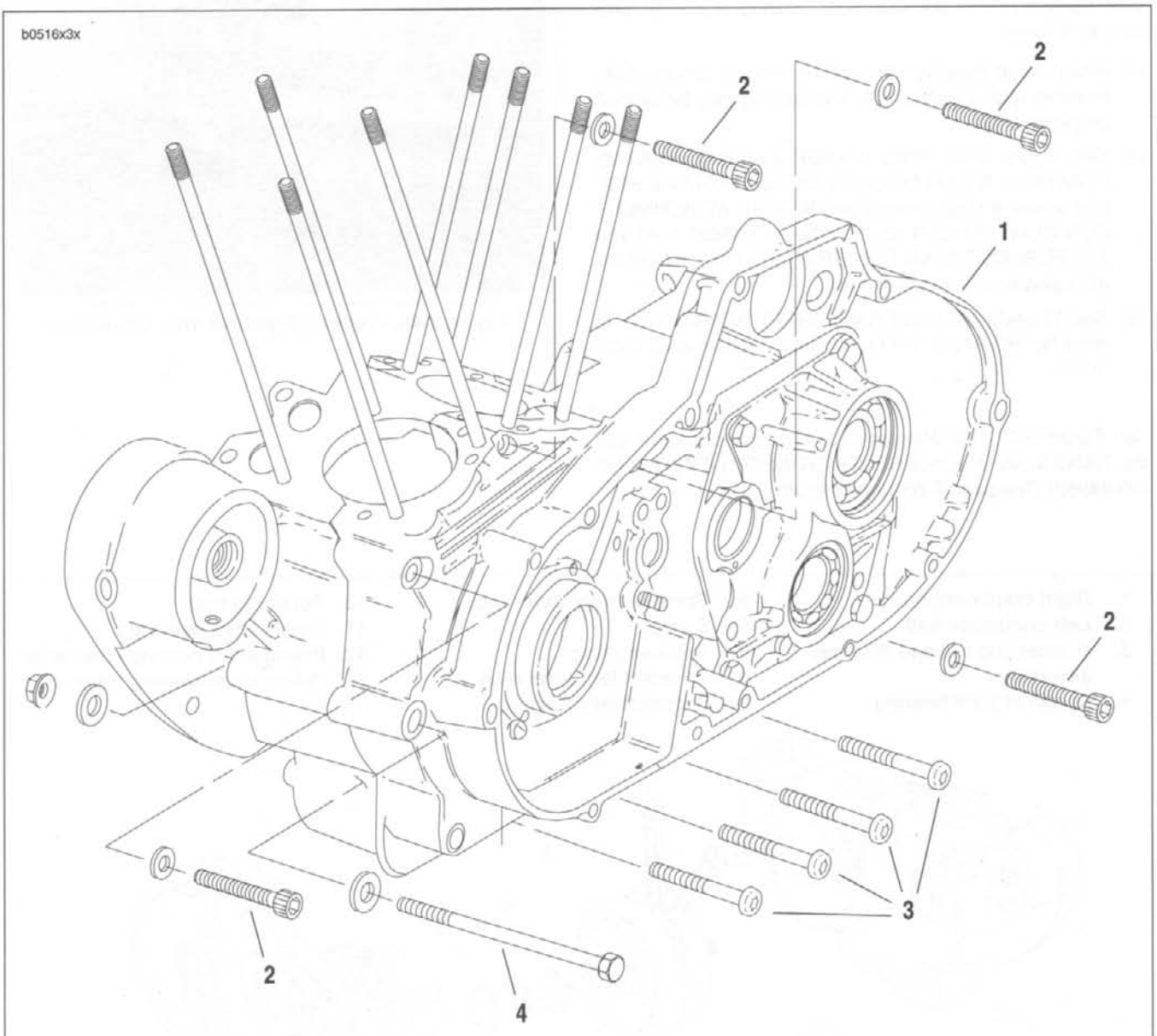
Crankcase Halves

1. Remove cylinder heads. See 3.5 CYLINDER HEAD.

CAUTION

After removing cylinders, install plastic or rubber hose over cylinder studs. Lifting or moving crankcase by grasping studs will cause cylinder stud damage.

2. Remove cylinders and pistons. See 3.6 CYLINDER AND PISTON.
3. Remove oil pump. See 3.13 OIL PUMP.
4. Remove gearcase components. See 3.17 GEARCASE COVER AND CAM GEARS (1999 models).
5. Remove primary cover and primary drive/clutch components. See PRIMARY CHAIN/DRIVE under 6.5 PRIMARY DRIVE/CLUTCH.
6. Remove starter motor. See 5.7 STARTER.
7. Remove transmission. See 6.7 TRANSMISSION CASE.
8. See Figure 3-94. Remove screws and rear engine mount bolt securing crankcase halves together.
9. Position crankcase on work bench, gearcase side up. Tap crankcase with plastic mallet to loosen top half and separate the halves.



1. **Crankcase**
2. **Upper case hex socket head screw – 5/16-18 X 2-1/2 in. long (4)**
3. **Bottom case T40 Torx bolt – 5/16-18 X 3/4 in. long (4)**
4. **Muffler mount bolt – 3/8-16 X 5-1/2 in. long (2, with washers and locknuts)**

Figure 3-94. Crankcase Hardware

⚠WARNING

The next step requires using a press. Wear eye protection and make certain set-up is stable. The pressure involved could cause parts to "fly out" with considerable force. Inadequate safety precautions could result in death or serious injury.

10. See Figure 3-95. Mount the left crankcase half and flywheel assembly on a press table, supporting crankcase on parallel bars. Press on end of sprocket shaft with arbor press until flywheel assembly is free from crankcase half. Do not drive flywheel assembly from crankcase half as flywheels may be knocked out of alignment.

NOTE

See Figure 3-96. If it is necessary to remove either the pinion shaft bearing (11) or sprocket shaft bearing (4 and 9), proceed as follows:

11. Pinion shaft bearing (11) will remain on pinion shaft. Remove retaining ring (10), and bearing may be slipped off pinion shaft.
12. See Figure 3-97. Place flywheel assembly in ROWE FLYWHEEL REBUILDING JIG (3) (Part No. HD-34813). Pull sprocket shaft bearing with WEDGE ATTACHMENT FOR CLAW PULLER (2) (Part No. HD-95637-46A) and ALL PURPOSE CLAW PULLER (1) (Part No. HD-95635-46) using bolts in place of jaws.
13. See Figure 3-98. Use CRANKSHAFT BEARING TOOL (Part No. HD-94547-101) to remove sprocket shaft outer races.

NOTE

See Figure 3-96. The retaining ring (7) may be removed with the TIMKEN SNAP RING REMOVER/INSTALLER (Part No. HD-44069). See page 3-80 for procedure.

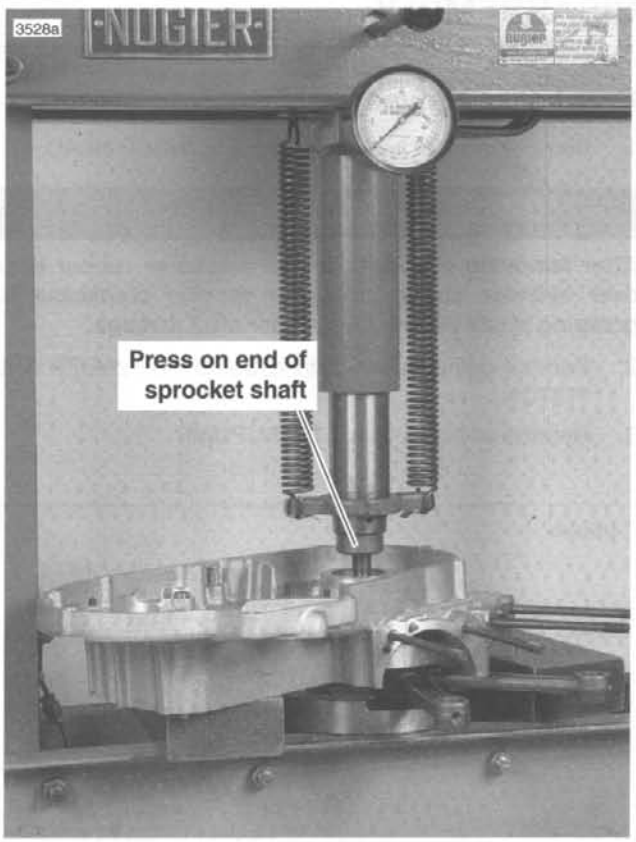


Figure 3-95. Pressing Flywheel from Crankcase

1. **Right crankcase half**
2. **Left crankcase half**
3. **Connecting rod and flywheel assembly**
4. **Sprocket right bearing**
5. **Sprocket right outer race**
6. **Spacer**
7. **Retaining ring**
8. **Sprocket left outer race**
9. **Sprocket left bearing**
10. **Retaining ring**
11. **Pinion shaft bearing**
12. **Pinion shaft bearing inner race**
13. **Pinion shaft bearing outer race**

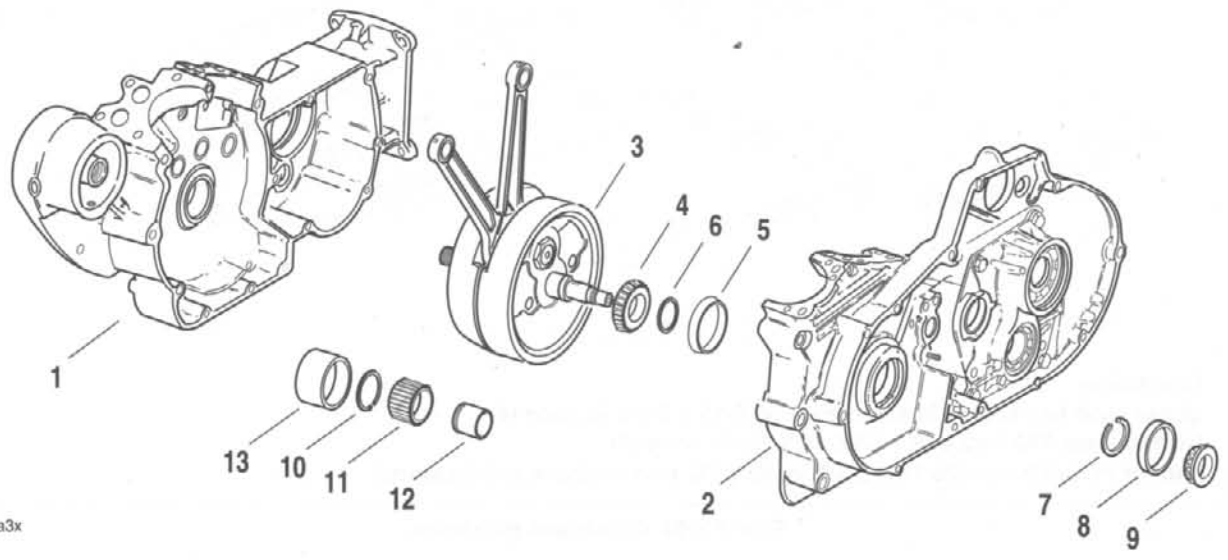


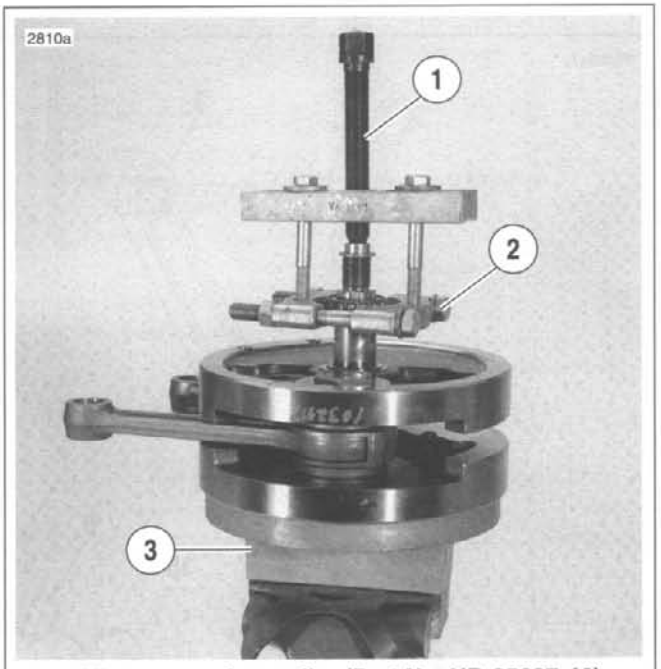
Figure 3-96. Crankcase and Flywheel Assembly

Flywheels

1. See Figure 3-99. Place flywheel assembly in rebuilding jig. Remove crank pin nut (1). Strike left flywheel with soft metal mallet at about 90° from crank pin hole on wheel periphery to loosen. Lift left flywheel (2) off crank pin.
2. Hold down crank pin bearing assembly (4) with a short length of pipe or tubing so connecting rods (3) may be slipped off bearings, then remove bearing assembly. Secure bearings (4) together in set until they are washed and refitted to crank pin.
3. Remove crank pin nut (8), then tap crank pin (6) out of flywheel and remove key (7).

CLEANING/INSPECTION

1. Wash all parts in solvent and blow dry with compressed air.
2. Examine crank pin for wear, grooving and pitting. If the surface is at all worn, replace with **new** crank pin.
3. Examine flywheel washers. If either washer is worn or grooved, it should be replaced. See REPLACING FLYWHEEL WASHERS below.
4. Examine connecting rod lower races.
   a. If they appear slightly grooved or shouldered where edge of bearing rollers ride, they may be lapped out. Install an oversize crank pin and **new** bearing.
   b. If they appear badly worn, grooved or pitted, install **new** rods. However, the preferred solution is installing an assembly with **new** bearings, crank pin and rods.
5. Inspect bearing for wear, pitting and heat discoloration. Replace as required.
6. Inspect crank pin, crank pin roller and connecting rods for correct freeplay.



1. **All purpose claw puller (Part No. HD-95637-46)**
2. **Wedge attachment (Part No. HD-95637-46A)**
3. **Rowe flywheel rebuilding jig (Part No. HD-**

Figure 3-97. Removing Sprocket Shaft Roller Bearing

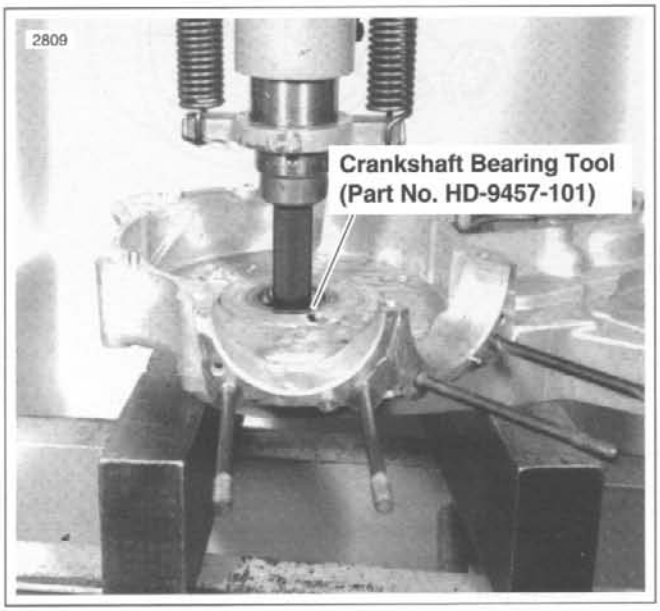
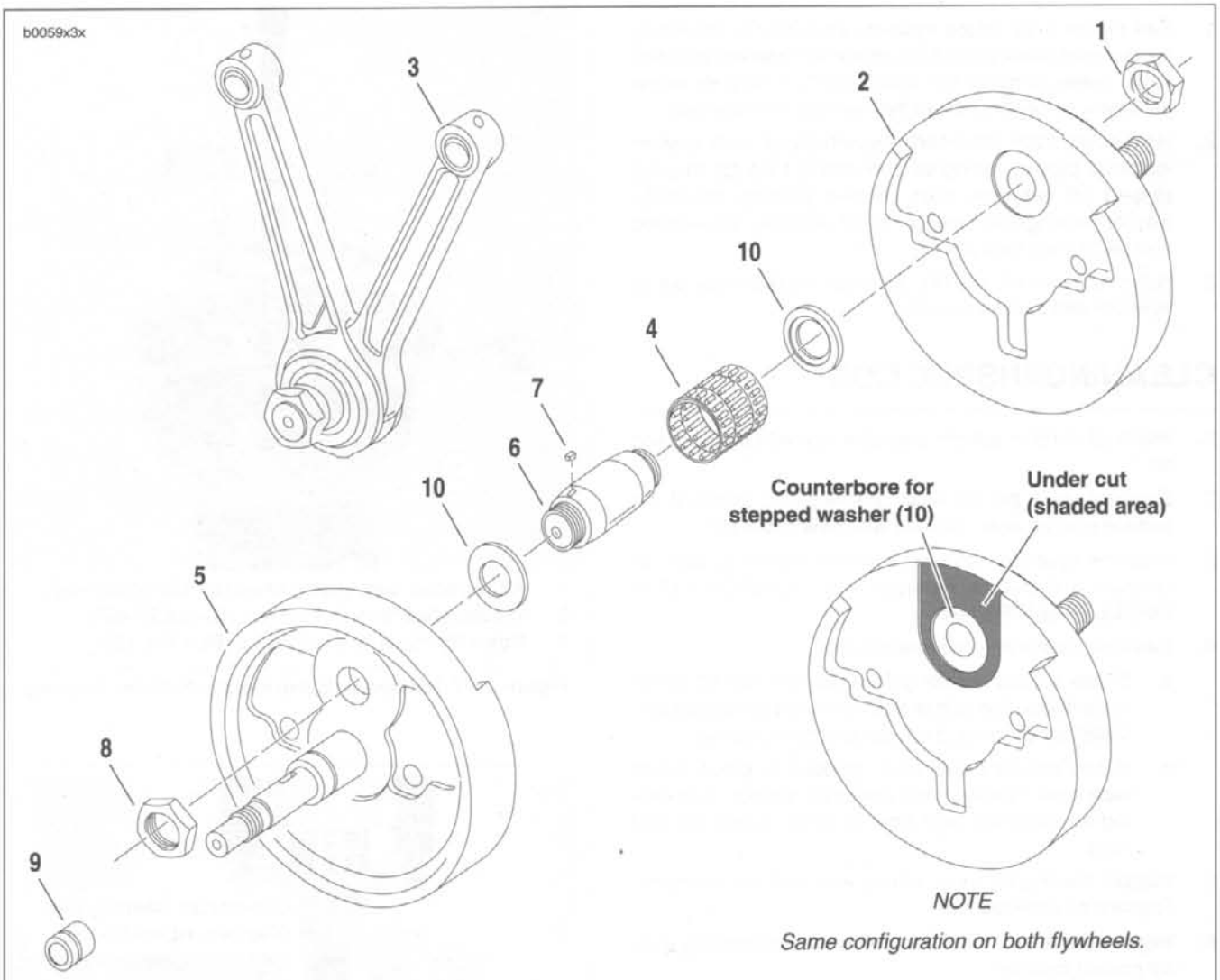


Figure 3-98. Sprocket Shaft Outer Race Removal



1. Crank pin nut (sprocket side)
2. Flywheel (sprocket side)
3. Connecting rods
4. Crank pin roller and retaining set
5. Flywheel (gear side)
6. Crank pin
7. Crank pin key
8. Crank pin nut (gear side)
9. Pinion bearing inner race
10. Flywheel washer (2)

Figure 3-99. 1999 Flywheel and Connecting Rod Assembly

Replacing Flywheel Washers

Replace worn flywheel washers as follows:

1. See Figure 3-100. The stepped flywheel washer is a close fit in flywheel recess. Washers are originally secured by punching flywheel metal tight against the washer at several points. It is usually necessary to drill a 1/8 in. (3.2 mm) or smaller hole at the outer edge of the washer to permit prying with a pointed tool.

NOTE

Drill hole only slightly deeper than thickness of washer. Avoid removing more material than necessary.

2. Before installing a **new** washer, scrape outer edge of recess where metal was punched against original washer. This will allow **new** washer to seat fully against recess bottom. If washer does not seat fully, forked rod will not have necessary clearance (side play).

CAUTION

Be sure stepped washers are installed with step facing crank pin bearing. Improper installation will damage washer and bearing set and cause accelerated wear and increased noise.

3. Carefully tap **new** washers into place. Use a punch to peen flywheel metal over washer edge to retain washer.

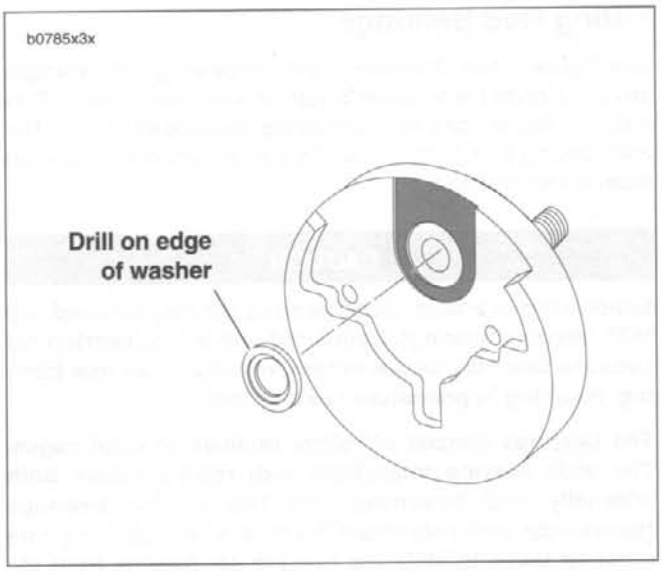


Figure 3-100. Flywheel Washer

Lapping Connecting Rod Races

Connecting rod lower races that are likely to clean up within range of oversize bearing rollers and are otherwise in serviceable condition, should be trued and sized with CONNECTING ROD LAPPING ARBOR (Part No. HD-96740-36).

1. Clean lapping arbor before using.
2. See Figure 3-101. Clamp lapping arbor into lathe chuck. Carefully load lap with #220 grit grinding compound, mixed with oil. Adjust lathe to turn at approximately 150-200 RPM.
3. Carefully slide connecting rod over lap. Adjust lap to a dragging, but free, fit in rod race.

NOTE

A loose lap will BELL MOUTH bearing races, so lap must be kept adjusted at all times.

4. Start lathe and work rod back and forth, over full length of lap. Hold rod as near race end as possible.
5. Check rod frequently. When rod is lapped true and all traces of pit marks or grooves are cleaned up, wash and blow rod dry.
6. Repeat lapping procedure for other rod race.
7. Bearing races should have a soft velvety appearance and be free of shiny spots.

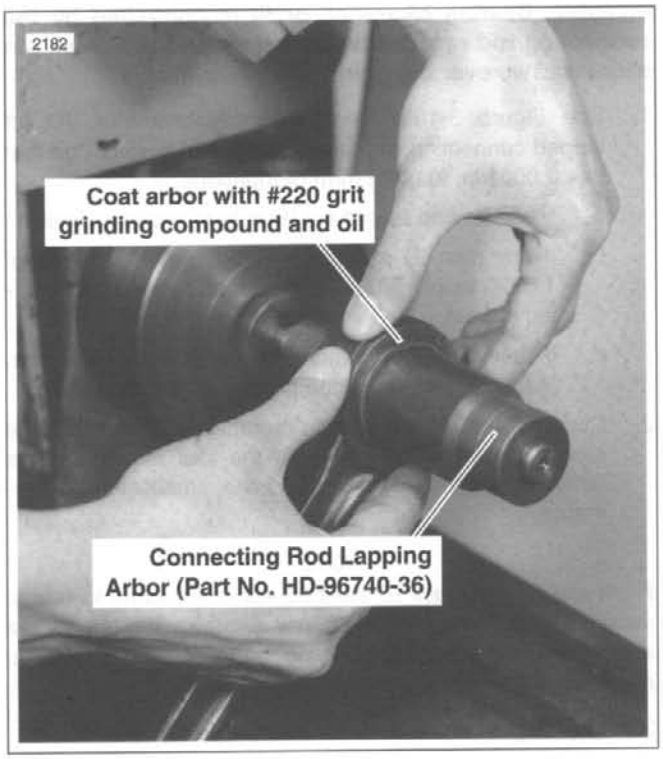


Figure 3-101. Lapping Connecting Rod Races

Fitting Rod Bearings

See Figure 3-102. The **new** crank pin bearing set packages are color coded with either a red or blue identification. This color coding is used by the bearing manufacturer only. The color coding DOES NOT indicate size selection for crank pin bearing replacement.

CAUTION

Either a red or a blue coded bearing set may be used. DO NOT intermix bearings from a red and a blue bearing set because this may cause excessive loading on one bearing, resulting in premature bearing failure.

The bearings consist of rollers retained in steel cages. The wide bearing (male/front rod) retains rollers both internally and externally. The two narrow bearings (female/rear rod) only retain the rollers externally, so care must be taken to slide the bearing set directly from the inner sleeve onto the crank pin; this will prevent the rollers from dropping out of the cage.

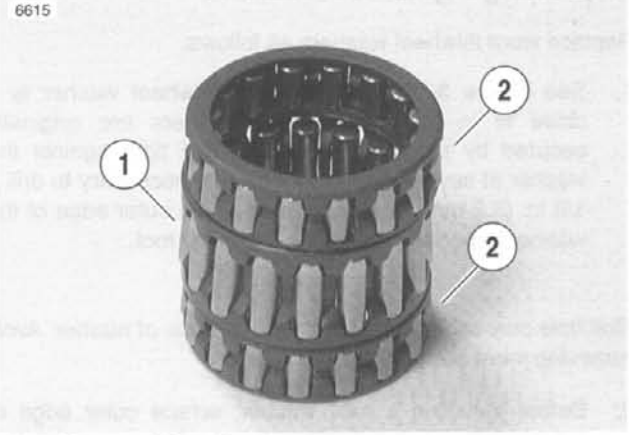
Only one size replacement bearing set (standard, either red or blue coding) is sold. Oversize bearings are not available. Bearing clearance or fit is controlled by the connecting rod race inside diameters and the crank pin diameter. Two oversize crank pins are available.

1. See Figure 3-103. Measure inside diameter (ID) of lapped connecting rod races. Use a dial bore gauge that has 0.0001 in. (0.0025 mm) graduations.
   a. Measure and record the ID at four places as shown.
   b. If any race ID exceeds SERVICE WEAR LIMIT of 1.6270 in. (41.3258 mm), replace races or connecting rod set.
   c. If race ID measurements are less than 1.6270 in. (41.3258 mm), continue procedure as follows:
2. Compare the measurements recorded in Step 1 with the ranges given in Table 3-15. If the four measurements taken in each race differ, use the smallest measurements.

NOTE

Front and rear rod race ID must be within the same tolerance range. The following example will illustrate the procedure necessary if the lapped connecting rod races on both rods do not fall in the same range.

3. Inspect parts to determine fitment. See Table 3-15.
   a. For example purposes, suppose the front connecting rod race ID is 1.6255 in. (41.2877 mm). This race ID requires a 0.0010 in. (0.0254 mm) oversize crank pin.
   b. For example purposes, suppose the rear connecting rod race ID is 1.6250 in. (41.2750 mm). This race ID requires the standard sized crank pin.
   c. Therefore, the rear connecting rod races must be lapped to accommodate the oversized crank pin. Front and rear races must have the same ID within 0.0002 in. (0.0051 mm).



1. **Front rod bearing**
2. **Rear rod bearings**

Figure 3-102. Crank Pin Bearing Set

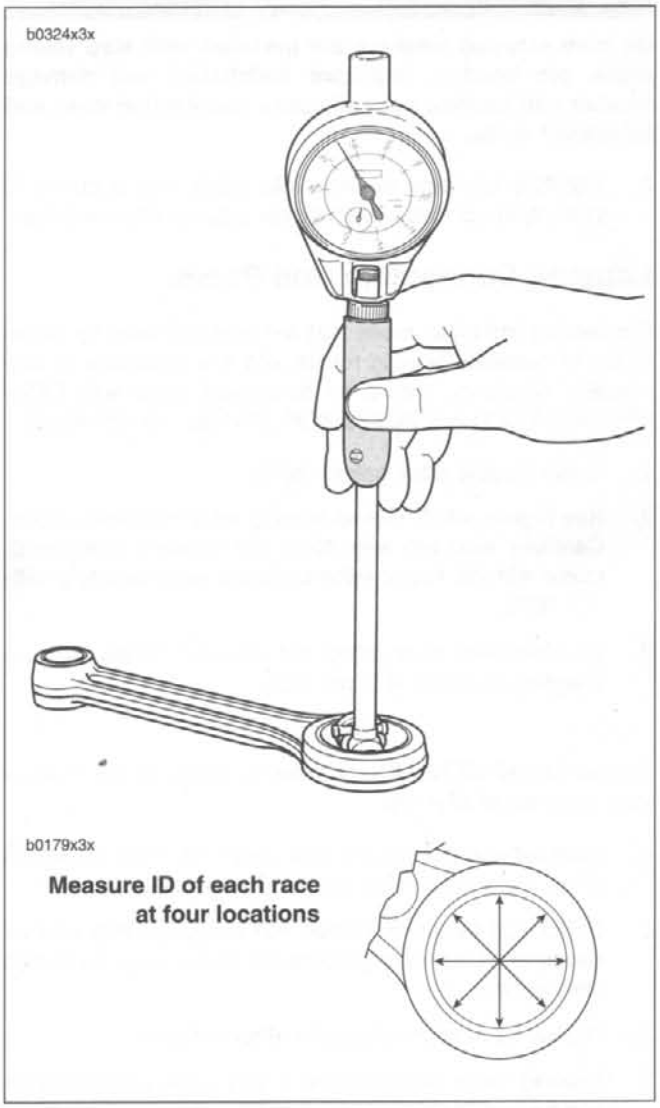


Figure 3-103. Measuring Connecting Rod Race Inside Diameter

NOTE

*Always use **new** bearings and crank pin after resizing (lapping) connecting rods to insure proper running clearance.*

4. See Figure 3-104. Two oversize (OS) crank pins are available. Identify OS crank pins by the blue or red paint dot on the ends of the pins. Standard size crank pins will not be marked.
   a. A blue dot indicates 0.0010 in. (0.0254 mm) OS.
   b. A red dot indicates 0.0020 in. (0.0508 mm) OS.

CAUTION

Fitting components tighter than recommended may result in seizing and bearing damage when heat expands the parts. Such damage requires component replacement.

5. Before assembling the flywheel assembly, recheck connecting rods specifications. See Table 3-16.
   a. Check difference in ID of two rear races.
   b. Check difference in ID between front and rear races.
   c. Check each race for roundness. Difference between largest and smallest ID measurement in any race must not exceed 0.00025 in. (0.00635 mm).

Fitting Sprocket Bearings

If flywheel end play is within tolerance, and if tapered roller bearings and races pass visual check and have no apparent wear, the same set may be reinstalled. Make certain all parts of bearing are installed in exactly the same order in which they were removed. If any part of bearing assembly is worn, entire assembly should be replaced.

Fitting Pinion Bearings

See Figure 3-96. A pressed-in bushing in the right crankcase half is the outer race (13). The inner race (12) is pressed on the pinion shaft.

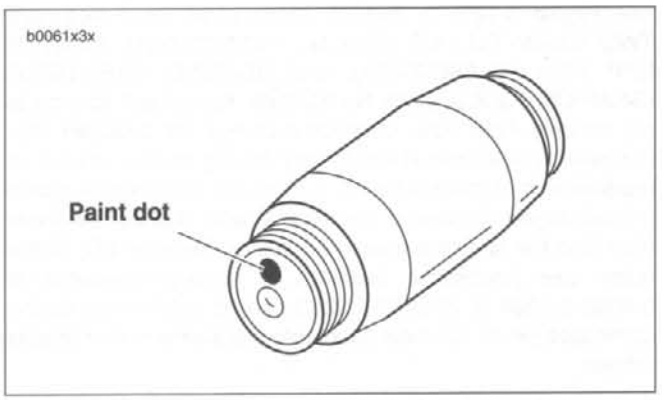


Figure 3-104. Oversize Crank Pin Identification

Table 3-15. Race Diameter and Crank Pin Size

CONNECTING ROD RACE ID REQUIRED	CRANK PIN REQUIRED	PAINT DOT
1.6245-1.6250 in. (41.2623-41.2750 mm)	Standard	none
1.6255-1.6260 in. (41.2887-41.3004 mm)	0.0010 in. oversize (0.0254 mm)	blue
1.6265-1.6270 in. (41.3131-41.3258 mm)	0.0020 in. oversize (0.0508 mm)	red
Greater than 1.6270 in. (41.3258 mm)	Replace races or connecting rod set.	

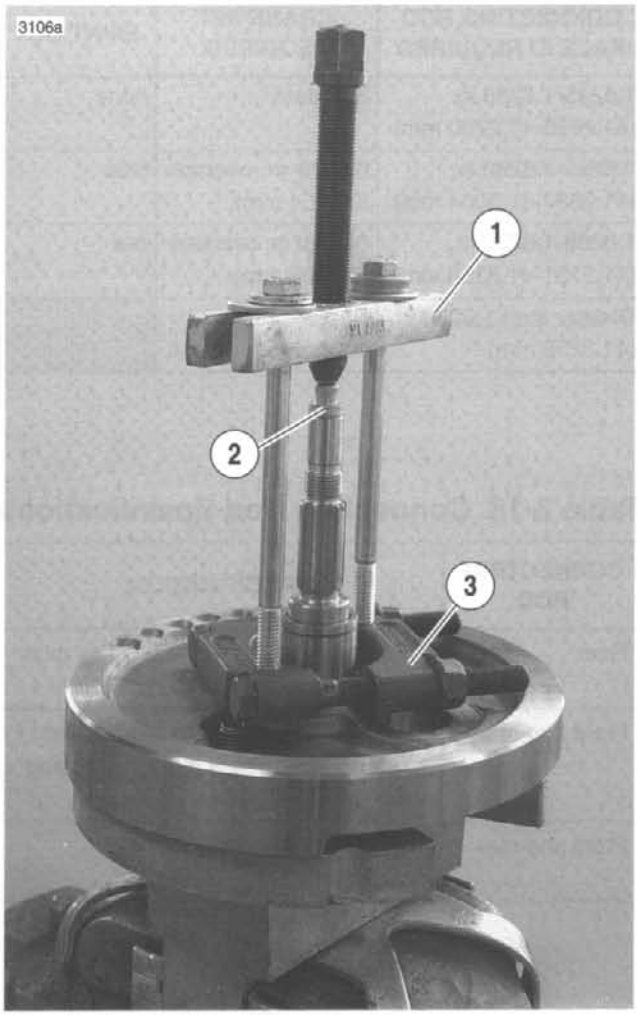
Table 3-16. Connecting Rod Specifications

CONNECTING ROD	SPECIFICATION
Rear	Difference in ID of two rear races must not exceed 0.0001 in. (0.0025 mm).
Front and rear	Difference in ID of races in front and rear connecting rods must not exceed 0.0002 in. (0.0051 mm).
Front and rear	Races must be round within 0.00025 in. (0.00635 mm).

See Figure 3-105. To remove pinion shaft inner race, use TWO CLAW PULLER (Part No. HD-97292-61), CENTER CAP (Part HD-95652-43A), and BEARING SEPARATOR (SNAP-ON TOOLS Stock No. CJ950). Apply heat to race to aid removal. Four sizes of pinion bearings are available. Pinion bearing selection at the factory, during engine rebuild, or replacement of crankcase set or flywheel assembly is based on the largest measured outside diameter (OD) of the inner race and the smallest measured inside diameter (ID) of the outer race (crankcase bushing). A running clearance of 0.0002-0.0008 in. (0.0051-0.0203 mm) is established during crankcase set or flywheel assembly replacement and engine rebuild.

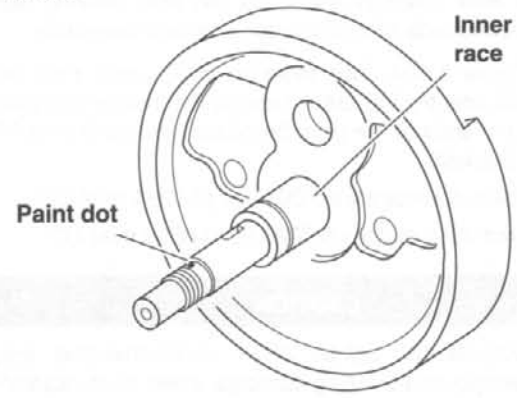
See Figure 3-106. Installed inner races are identified at the factory as shown.

See Figure 3-107. Outer races are identified at the factory as shown.



1. **Puller (Part No. HD-97292-61)**
2. **Center cap (Part No. HD-95652-43A)**
3. **Bearing separator (Snap-On Part No. CJ950)**

Figure 3-105. Pulling Pinion Shaft Inner Race

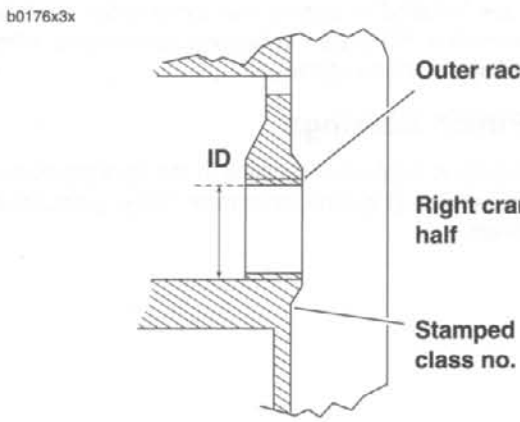


RACE OD	CLASS	IDENTIFICATION*
1.2498-1.2500 in. (31.7449-31.7500 mm)	A	White
1.2496-1.2498 in. (31.7398-31.7449 mm)	B	Green

*** Paint dot on end of spline**

SERVICE WEAR LIMIT: 1.2492 in. (31.7297 mm)

Figure 3-106. Factory Inner Race Sizes



RACE ID	CLASS NO.	STAMPED IDENTIFICATION*
1.5646-1.5648 in. (39.7408-39.7459 mm)	1	1
1.5648-1.5650 in. (39.7459-39.7510 mm)	2	2
1.5650-1.5652 in. (39.7510-39.7561 mm)	3	3

*** Stamped number inside crankcase near race**

SERVICE WEAR LIMIT: 1.5672 in. (39.8069 mm)

Figure 3-107. Factory Outer Race Sizes

NOTE

The different sizes of crankcase sets and flywheel assemblies will not have separate part numbers. That is, a replacement crankcase set may have a class 1, 2 or 3 pinion outer race. Replacement flywheel assemblies will have either a class A or B inner race.

See Figure 3-108. Pinion bearings are identified as shown.

BEARING SELECTION

Select bearings using the identification information given for inner and outer races and bearings. See Table 3-17.

NOTE

If either inner or outer race show wear, measure both races to confirm correct bearing fit.

1. Use a dial bore gauge to measure and record ID of outer race. Take four measurements on ID where bearing rollers ride.
   a. If the largest measurement is larger than 1.5672 in. (39.8069 mm) or the required lapping to remove wear marks would enlarge bore beyond 1.5672 in., continue at Step 5.
   b. If largest measurement is 1.5672 in. (39.8069 mm) or less, cover the cam bearings with masking tape to prevent debris from entering bearings. Assemble crankcase halves.

NOTE

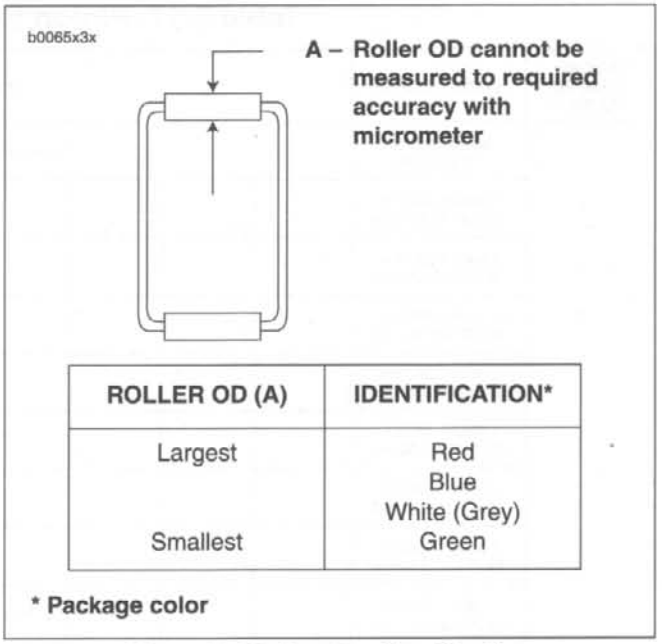
The next step requires lapping the outer race. To keep sprocket shaft and pinion shaft bearings aligned the lap must be supported by an adaptor or pilot in the left crankcase half.

2. See LAPPING ENGINE MAIN BEARING RACES. Lap race until all wear marks are removed.
3. Measure and record ID of race at four places.
4. Check measurements against these specifications:

   Largest ID measured: 1.5672 in. (39.8069 mm) or less
   Roundness of ID: within 0.0002 in. (0.0051 mm)
   Taper: within 0.0002 in. (0.0051)
   a. If lapping increased bore ID to larger than 1.5672 in. (39.8069 mm), go to Step 5.
   b. If roundness or taper do not meet specifications, continue lapping until specifications are met.
   c. If all specifications are met, continue at Step 7 to remove and size inner race.
5. Press the outer race from the right crankcase. Press **new** outer race into crankcase flush with inside edge of cast-in insert.

   See Figure 3-109. Dimensions are shown for fabrication of tools used in pressing the outer race into or out of crankcase.
6. The **new** outer race must be lapped slightly to true and align with left case bearing and to meet the following specifications. See LAPPING ENGINE MAIN BEARING RACES.

   ID: 1.5646 - 1.5652 in. (39.7408 - 39.7561 mm)
   Roundness: within 0.0002 in. (0.0051 mm)
   Taper: within 0.0002 in. (0.0051 mm)
   Surface finish: 16 RMS



ROLLER OD (A)	IDENTIFICATION*
Largest	Red
	Blue
	White (Grey)
Smallest	Green

*** Package color**

Figure 3-108. Bearing Identification

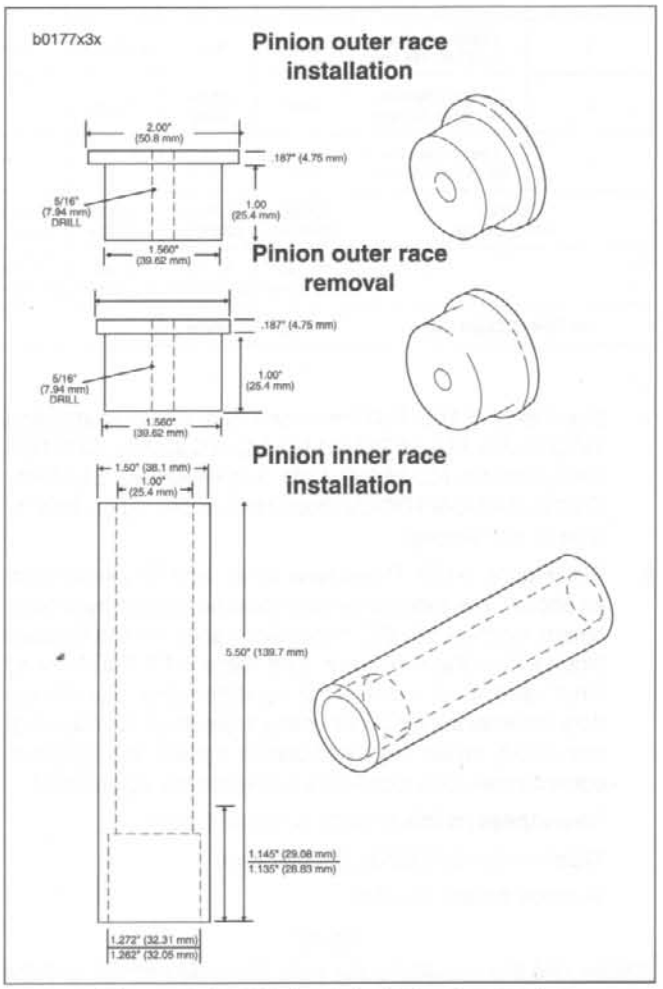


Figure 3-109. Pinion Shaft Bearing Tools

Table 3-17. Pinion Shaft Bearing Selection

FACTORY STAMPED NUMBER	OUTER RACE ID	BEARING SIZE AS IDENTIFIED BY COLOR CODING										
	over 1.5672 in. 39.807 mm	Service Wear Limit Exceeded – Replace Outer Race and Resize										
	1.5670-1.5672 in. 39.802-39.807 mm											Red
	1.5668-1.5670 in. 39.797-39.802 mm										Red	Blue
	1.5666-1.5668 in. 39.792-39.797 mm									Red	Blue	White-Gray
	1.5664-1.5666 in. 39.787-39.792 mm								Red	Blue	White-Gray	Green
	1.5662-1.5664 in. 39.781-39-787 mm							Red	Blue	White-Gray	Green	
	1.5660-1.5662 in. 39.776-39.781 mm						Red	Blue	White-Gray	Green		
	1.5658-1.5660 in. 39.771-39.776 mm					Red	Blue	White-Gray	Green			
	1.5656-1.5658 in. 39.766-39.771 mm				Red	Blue	White-Gray	Green				
	1.5654-1.5656 in. 39.761-39.766 mm			Red	Blue	White-Gray	Green					
	1.5652-1.5654 in. 39.756-39.761 mm		Red	Blue	White-Gray	Green						
3	**1.5650-1.5652 in. 39.751-39.756 mm**	**Red**	**Blue**	White-Gray	Green							
2	**1.5648-1.5650 in. 39.746-39.751 mm**	**Blue**	**White-Gray**	Green								
1	**1.5646-1.5648 in. 39.741-39.746 mm**	**White-Gray**	**Green**									
INNER RACE OD (In)		**1.2496-1.2498 in.**	**1.2498-1.2500 in.**	1.2500-1.2502 in.	1.2502-1.2504 in.	1.2504-1.2506 in.	1.2506-1.2508 in.	1.2508-1.2510 in.	1.2510-1.2512 in.	1.2512-1.2514 in.	1.2514-1.2516 in.	1.2516-1.2518 in.
		31.740 31.745 mm	31.745 31.750 mm	31.750-31.755 mm	31.755-31.760 mm	31.760-31.765 mm	31.765-31.770 mm	31.770-31.755 mm	31.775-31.780 mm	31.780-31.786 mm	31.786-31.791 mm	3.791-31.796 mm
FACTORY COLOR CODE		**Green**	**White**									

7. See Figure 3-105. Pull inner race from pinion shaft using TWO CLAW PULLER (Part No. HD-97292-61), CENTER CAP (Part No. HD-95652-43A), and BEARING SEPARATOR (SNAP-ON TOOLS Stock No. CJ950). Apply heat to race to aid removal.
8. See Figure 3-110. Press **new** inner race on pinion shaft as shown. The **new** inner race must be ground by a competent machinist to OD dimension range for the finished lapped ID of the outer race. See Table 3-17. The finished inner race must meet these specifications. For necessary dimensions for constructing a press-on tool see Figure 3-109. When the tool bottoms against the flywheel, correct inner race location is automatically established.

   Roundness: within 0.0002 in. (0.0051 mm)

   Taper: within 0.0002 in. (0.0051 mm)

   Surface finish: 16 RMS

NOTE

Always use the smallest outer race ID measurement and the largest OD inner race measurement when selecting bearings.

9. The following example illustrates how to determine the required inner race OD.
   a. See Table 3-17. For example purposes, suppose the smallest outer race ID measurement is 1.5651 in. (39.754 mm). This requires an inner race OD range of 1.2496-1.2504 in. (31.740 - 31.760 mm).

NOTE

Have machinist grind outer race to center or middle of required OD range. This will prevent grinding outer race undersize and gives a more easily achieved tolerance range.

   b. Grind inner race. Measure OD at four places. Check that specifications in Step 8 are met.
   c. For example purposes, suppose the largest inner race OD measurement after grinding is 1.2499 in. (31.747 mm) OD.
   d. With a 1.5651 in. (39.754 mm) ID outer race and a 1.2499 in. (31.747 mm) OD inner race, a blue bearing is required.

Lapping Engine Main Bearing Races

1. Secure right and left crankcase halves with three crankcase stud bolts (top center and bottom left and right). The sprocket shaft bearing outer races and large spacer must be installed in left crankcase.
2. See Figure 3-111. Obtain CRANKCASE MAIN BEARING LAPPING TOOL (Part No. HD-96710-40B). Assemble CRANKCASE MAIN BEARING LAP (Part No. HD-96718-87) to lapping handle. Assemble guide sleeve to sprocket shaft bearing bushing. Sleeves, for use with tapered bearing, are assembled to case with bearings and small spacer collar. Finger-tighten the sleeve parts.
3. Insert lap shaft with arbor assembled through pinion bearing bushing and into guide sleeve. Tighten arbor expansion collars using a length of 0.156 in. (3.962 mm) rod as spanner until arbor begins to drag. Do not adjust arbor snug in bushing or bushing will "bell," a condition where hole is larger at ends than it is in the center.
4. Withdraw arbor far enough to coat lightly with 220 grit lapping compound. Do not apply a heavy coat. Reposition lap in bushing and turn handle at moderate hand speed. Work lap back and forth in bushing, as it is revolved, to avoid grooving and tapering.
5. At frequent intervals, remove lap from crankcase, wash and inspect bushing. Lapping is completed when entire bushing surface has a dull, satin finish rather than a glossy, smooth appearance. If necessary, flush off lap in cleaning solvent, air dry and apply fresh, light coat of fine lapping compound.

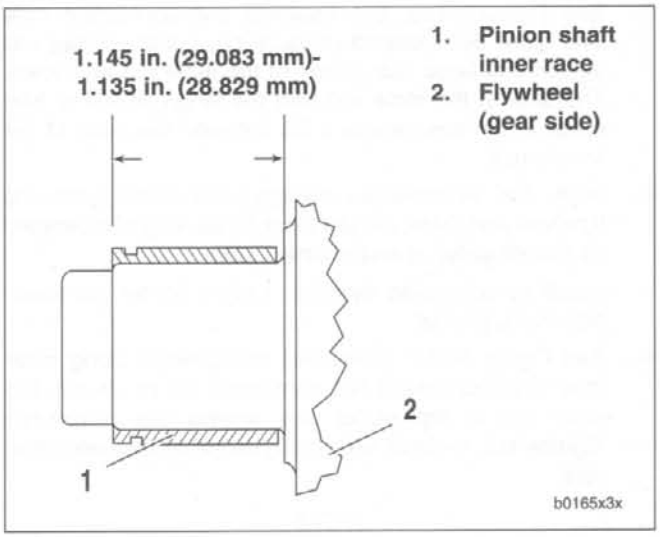


Figure 3-110. Inner Race Location

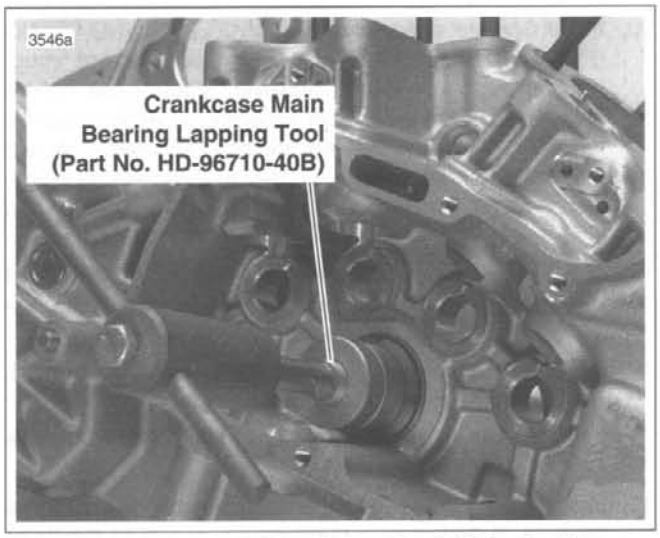


Figure 3-111. Lapping Pinion Shaft Main Bearing

ASSEMBLY

Flywheels

After correct connecting rod bearing fit has been attained, clean and assemble parts as follows:

1. Carefully clean all flywheel components using a non-petroleum-based solvent, such as LOCTITE CLEANING SOLVENT or electrical contact cleaner. Thoroughly dry all components.
2. See Figure 3-99. Apply two drops of LOCTITE 620 RETAINING COMPOUND to the crank pin threads, and apply no more than two drops to the nut bearing faces.

CAUTION

Do not apply any LOCTITE THREADLOCKER COMPOUND or RETAINING COMPOUND to shaft tapers. Any material on shaft tapers will cause component damage.

3. Assemble crank pin (6) to gear-side flywheel (5) making sure that key (7) is in proper position. Tighten gear-side crank pin nut to 150-185 ft-lbs (203.4-250.8 Nm).
4. Place gear-side flywheel assembly in rebuilding jig with crank pin pointing up. Wipe crank pin taper clean.

5. See Figure 3-112. Slip bearings and connecting rods over crank pin. Assemble angular boss of the female rod adjacent to large radius side of the male rod as shown. The side of the male rod with the larger radius is narrower in the area where it fits between the forks of the female rod.
6. Verify that oil passages through pinion shaft, gear-side flywheel and crank pin are clear by blowing compressed air into oil galley at end of pinion shaft.
7. Install sprocket-side flywheel. Lightly tighten sprocket-side crank pin nut.
8. See Figure 3-113. Hold steel straightedge along outer face of wheel rims at 90° from crank pin as shown. Tap outer rim of top wheel until wheels are concentric. Tighten nut, recheck with straightedge at frequent intervals.

NOTE

Use soft metal hammer to realign wheels.

9. Tighten sprocket-side crank pin nut to 150-185 ft-lbs (203.4-250.8 Nm).
10. Install flywheel assembly in FLYWHEEL TRUING STAND (Part No. HD-96650-80). Adjust so centers are snug. Wheels must turn freely; however, shafts must not be loose in centers. If flywheel assembly is either loose or too tight, indicators will not indicate accurately. Adjust indicators to take reading as near to flywheels as possible. Pointers should read at about the middle of the scales.
    a. Turn flywheels slowly and observe the movement of indicator pointers. Movement toward flywheels indicate high points of shafts.
    b. Find highest point of each shaft. Use chalk to mark flywheel rims at those points.
    c. Remove flywheel from stand. Make corrections as follows:
11. See Figure 3-114. Flywheel may be out of true three ways (a, b and c) or a combination of two of the three ways.
    a. When wheels are both out of true as indicated in A, tighten C-clamp on rims or wheels opposite crank pin. Lightly tap the rim at the crank pin with lead or copper mallet.
    b. When wheels are both out of true as indicated in B, drive a hardwood wedge between the wheels opposite the crank pin. Lightly tap the rims near the crank pin with a lead or copper mallet.
    c. When wheels are out of true as indicated in C, strike the rim of the wheel a firm blow at about 90° from crank pin on high side.
    d. When wheels are out of true in a combination of any of the conditions shown, correct C first, tapping rim of offending wheel only. Then correct condition A or B.

NOTE

The number of blows required and how hard they should be struck depends on how far shafts are out of true and how tight nuts are drawn. Always remove the flywheels from the stand, and strike the flywheel rim only at 90° to the crank pin. Use only a soft metal hammer. Never strike wheels a hard blow near crank pin. This could result in a broken crank pin.

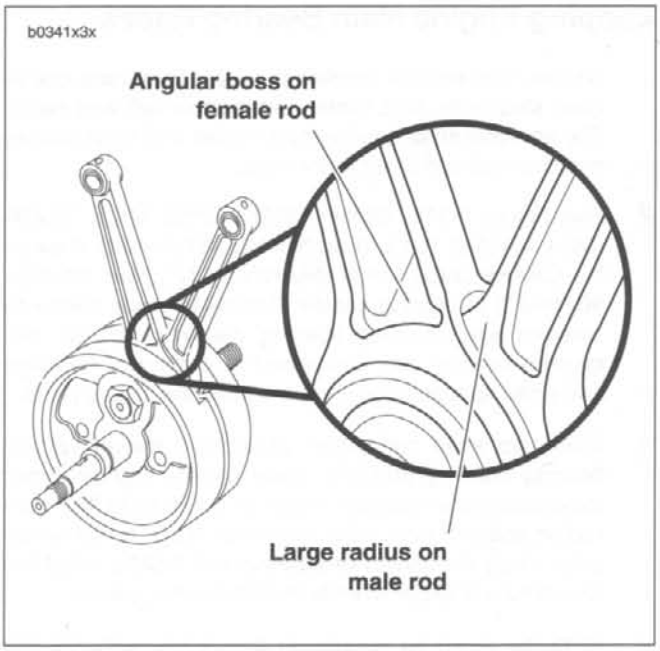


Figure 3-112. Installing Connecting Rods

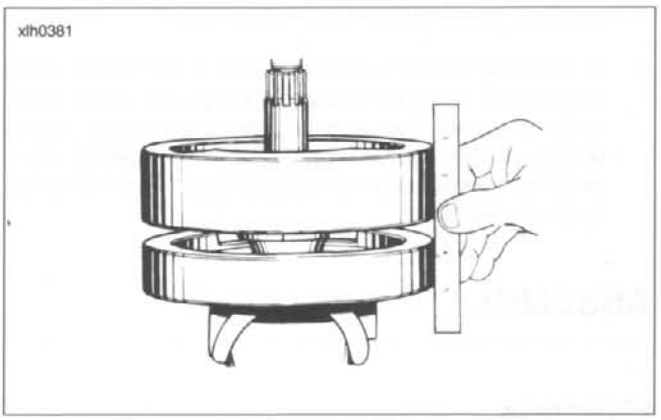


Figure 3-113. Squaring Flywheel Faces

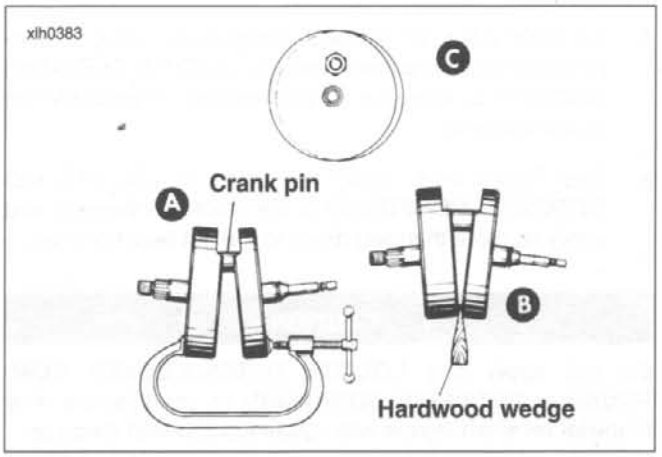


Figure 3-114. Correcting Flywheel Alignment

12. Readjust centers, revolve wheels and take reading from indicator. Repeat truing operation until indicated shaft runout does not exceed 0.001 in. (0.025 mm).

NOTE

Each graduation on indicator is 0.002 in. (0.051 mm).

13. If it is impossible to true wheels, check for:
    a. Cracked flywheel.
    b. Damaged or enlarged tapered hole.
    c. Sprocket or pinion shaft worn out-of-round at surface where indicator reading is being taken.
14. See Figure 3-115. When wheels are true, check connecting rod side play with thickness gauge as shown. If it is greater than tolerance shown in SERVICE WEAR LIMITS draw up crank pin nuts until within tolerance. Insufficient play between rods and flywheel face is caused by one of the following conditions:
    a. Flywheels and crank pin assembled with oil on tapers and nut over-tightened. Disassemble, clean and reassemble.
    b. **New** flywheel washers installed and not fully seated. Disassemble, inspect, replace deepest seating flywheel or crank pin. As last resort, grind down width of forked rod.
    c. Taper holes enlarged as a result of having been taken apart several times. Replace deepest seating wheel.
    d. Cracked flywheel at tapered hole. Replace flywheel.
15. After rod side play is checked and adjusted, check that crank pin nut is tightened to specified torque. Recheck wheel trueness on truing device. Correct any runout as above.

Crankcase Halves

Lubricate all parts with Harley-Davidson 20W50 engine oil, and proceed as follows:

1. See Figure 3-116. The original retaining ring (1) is left in place to avoid damaging the bearing bore of the left crankcase half. Verify that gap in retaining ring (1) is aligned with oil supply hole (2) in left crankcase half bearing bore.

NOTE

See Figure 3-117. Use SPROCKET SHAFT BEARING OUTER RACE INSTALLATION TOOL (1, 2) (Part No. HD-39458) to install left and right outer races (4, 5) of sprocket shaft tapered roller bearings into left crankcase half (6). Always install left outer race (4) prior to installing right outer race (5) because the installer base (1) is usable only when you follow this sequence of race installation.

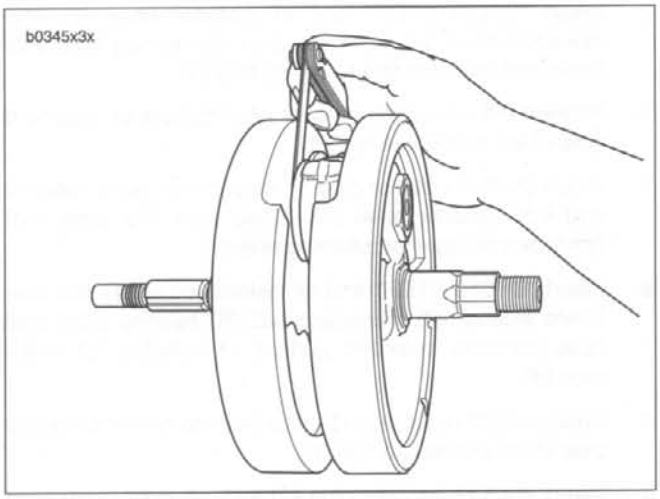
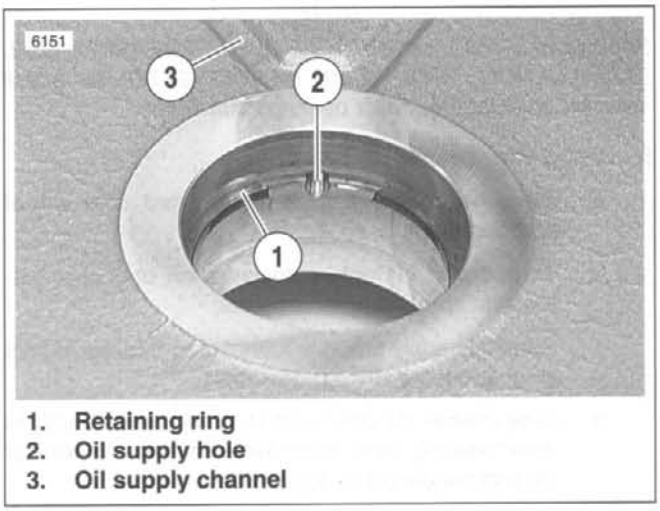
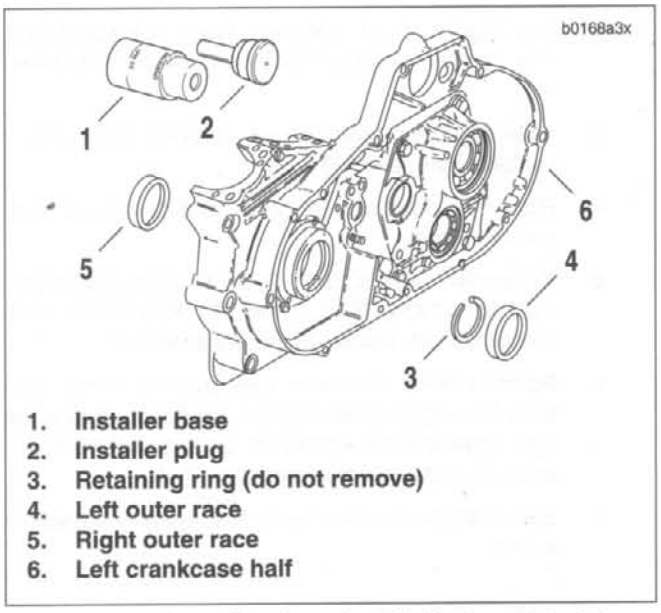


Figure 3-115. Checking Connecting Rod Side Play



1. **Retaining ring**
2. **Oil supply hole**
3. **Oil supply channel**

Figure 3-116. Retaining Ring



1. **Installer base**
2. **Installer plug**
3. **Retaining ring (do not remove)**
4. **Left outer race**
5. **Right outer race**
6. **Left crankcase half**

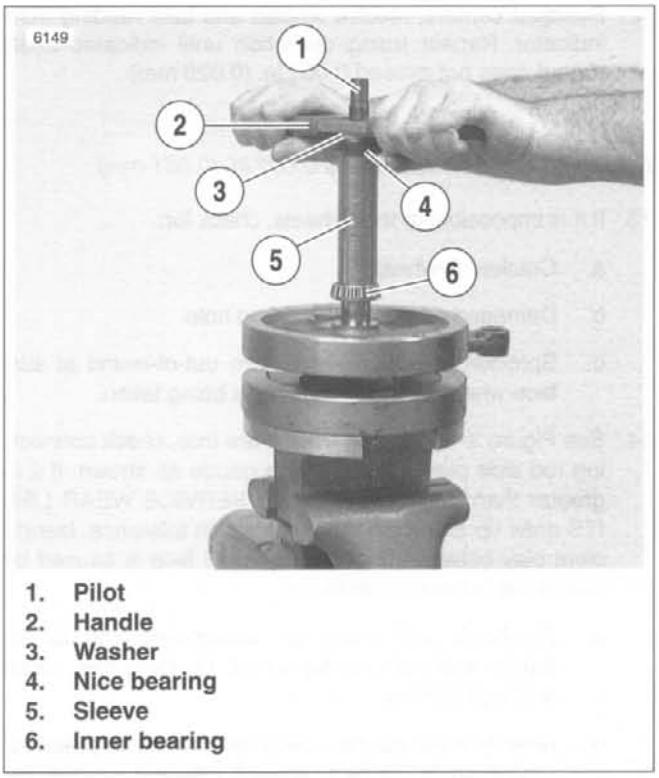
Figure 3-117. Installing Sprocket Shaft Bear Outer Races

2. Insert "SPORTSTER" end of installer base (1) into inboard side of left crankcase half (6) bearing bore until base contacts installed retaining ring (3).
3. Position left outer race (4) over bearing bore on outboard side of left crankcase half (6).
4. Insert shaft of installer plug (2) through left outer race (4) and into installer base (1). Press race into bore until firmly seated against retaining ring (3).
5. Insert "SPORTSTER" end of installer base (1) into outboard side of left crankcase half (6) bearing bore until base contacts outboard surface of installed left outer race (4).
6. Position right outer race (5) over bearing bore on inboard side of left crankcase half (6).
7. Insert shaft of installer plug (2) through right outer race (5) and into installer base (1). Press race into bore until firmly seated against retaining ring (3).

NOTE

See Figure 3-118. Use SPROCKET SHAFT BEARING/SEAL INSTALLATION TOOL (Part No. HD-42579) to install sprocket shaft tapered roller bearings and seal.

8. Install inner bearing (6).
   a. Place **new** bearing, small end upward, over end of sprocket shaft.
   b. Thread pilot (1) onto sprocket shaft until pilot bottoms on sprocket shaft shoulder.
   c. Sparingly apply graphite lubricant to threads of pilot shaft to ensure smooth operation.
   d. Slide sleeve (5) over pilot (1) until sleeve contacts inner bearing race. Install Nice bearing (4), washer (3) and handle (2) on top of sleeve.
   e. Rotate handle clockwise until bearing (6) contacts flywheel shoulder. Remove tool from sprocket shaft.
9. See Figure 3-96. Install spacer (6) and outer bearing (9).
   a. See Figure 3-119. Carefully place crankcase half over sprocket shaft so that it rests flat on inner bearing.
   b. Slide **new** inner spacer over sprocket shaft until it contacts inner bearing race.
   c. Place **new** outer bearing, small end downward, over sprocket shaft.
   d. Assemble SPROCKET SHAFT BEARING/SEAL INSTALLATION TOOL (Part No. HD-42579) onto sprocket shaft. Follow procedure in Step 8.
   e. Rotate handle clockwise until bearing firmly contacts inner spacer. Inner and outer bearings must be tight against inner spacer for correct bearing clearance. Remove tool from sprocket shaft.
   f. Spin crankcase half to verify that flywheel assembly is free.



1. **Pilot**
2. **Handle**
3. **Washer**
4. **Nice bearing**
5. **Sleeve**
6. **Inner bearing**

Figure 3-118. Inner Bearing Installation

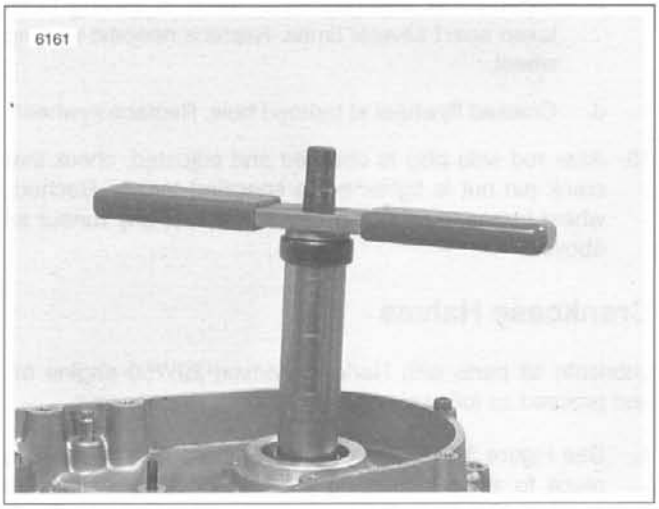


Figure 3-119. Installing Flywheel Spacer and Outer Bearing

10. See Figure 3-120. Install **new** spacer in seal ID. With the open (lipped) side facing outward, center seal/spacer assembly over bearing bore.

CAUTION

Do not remove the spacer after installation or the new seal will have to be discarded and the procedure repeated.

11. See Figure 3-121. Install bearing seal and spacer.
    a. Center seal/spacer driver (2) over seal, so that the sleeve (smaller OD) seats between seal wall and garter spring.
    b. Assemble SPROCKET SHAFT BEARING/SEAL INSTALLATION TOOL (1) (Part No. HD-42579) and SPROCKET SHAFT SEAL/SPACER INSTALLER (Part No. HD-42774) onto sprocket shaft. Follow procedure in Step 8.
    c. Rotate handle clockwise until the spacer makes contact with the bearing. Remove tool from sprocket shaft.
12. See Figure 3-122. Install pinion shaft bearing.
    a. Lubricate pinion shaft bearing with engine oil.
    b. Slip bearing on pinion shaft.
    c. Install **new** retaining ring in groove of pinion shaft bearing inner race.
13. Assemble crankcase halves together.
    a. Apply a thin coat of DOW CORNING SILASTIC or 3-M 800 sealant to crankcase joint faces.
    b. Slide pinion shaft through outer race in right crankcase.
    c. Attach crankcase halves using hardware shown in Figure 3-94.
    d. Tighten the 1/4-in. fasteners to 70-110 **in-lbs** (7.9-12.4 Nm)
    e. Tighten the 5/16-in. fasteners to 15-19 ft-lbs (20.3-25.8 Nm).

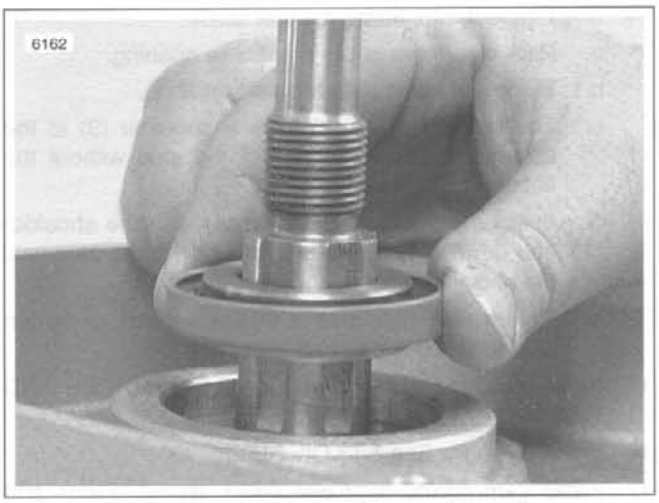
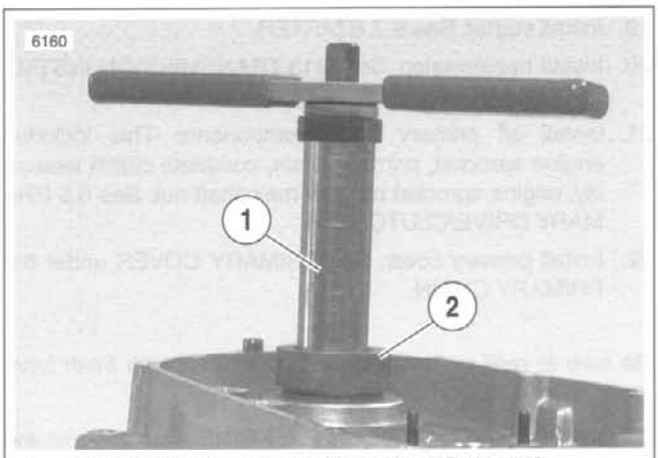


Figure 3-120. Install Spacer in Seal



1. **Bearing/seal installer (Part No. HD-42579)**
2. **Seal/spacer installer (Part No. HD-42774)**

Figure 3-121. Install Bearing Seal/Spacer

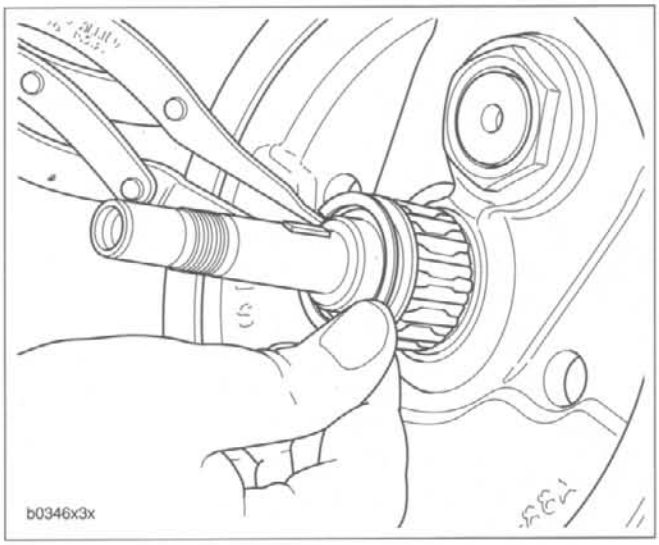


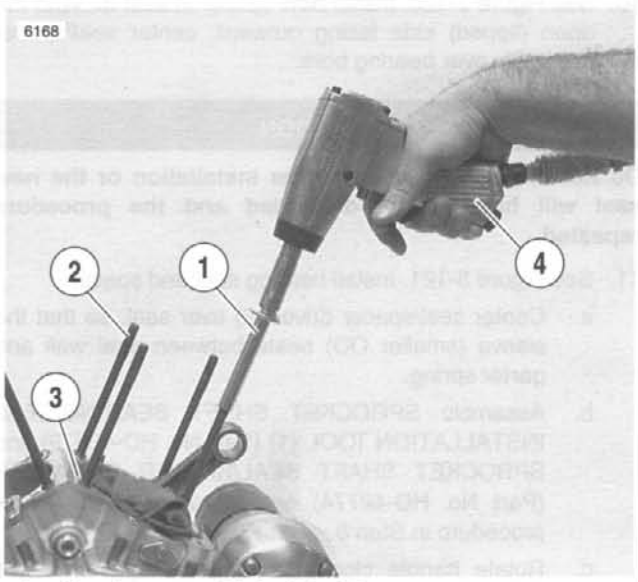
Figure 3-122. Pinion Shaft Bearing

14. See Figure 3-123. Install cylinder studs.
    a. Pack clean towels into crankcase opening.
    b. Place a steel ball into a head screw (1).
    c. The cylinder studs (2) have a shoulder (3) at the lower end. Place the end of the stud without the shoulder into the head screw.
    d. Install the stud in the crankcase with the shoulder end down. Use an air gun (4) to drive the stud until the shoulder reaches the crankcase.
    e. Remove air gun. Use a torque wrench to tighten stud to 10-20 ft-lbs (13.6-27.1 Nm).
15. Install pistons and cylinders. See 3.6 CYLINDER AND PISTON.
16. Install oil pump. See 3.13 OIL PUMP.
17. Install cam gears, gearcase cover, tappet guides and tappets. See 3.17 GEARCASE COVER AND CAM GEARS (1999 models).
18. Install cylinder heads. See 3.5 CYLINDER HEAD.
19. Install starter. See 5.7 STARTER.
20. Install transmission. See 6.13 TRANSMISSION INSTALLATION AND SHIFTER PAWL ADJUSTMENT.
21. Install all primary drive components. This includes engine sprocket, primary chain, complete clutch assembly, engine sprocket nut and mainshaft nut. See 6.5 PRIMARY DRIVE/CLUTCH.
22. Install primary cover. See PRIMARY COVER under 6.2 PRIMARY CHAIN.

NOTE

Be sure to refill transmission to proper level with fresh lubricant. See 1.12 CLUTCH.

23. See 3.4 INSTALLING THE ENGINE and perform the applicable steps.



1. **Head screw with ball inside**
2. **Cylinder stud**
3. **Shoulder on cylinder stud**
4. **Air gun**

Figure 3-123. Cylinder Studs

MODEL YEAR CHANGE

All 2000 Model Year Buell Thunderstorm™ engines have a **new** straight, pressed-in crankpin and low-inertia flywheel. The new flywheel is serviced as an assembly (is not disassembled).

GENERAL

CAUTION

If engine is removed from chassis, do not lay engine on primary side. Placing engine on primary side will damage clutch cable end fitting. If fitting is damaged, clutch cable must be replaced.

Remove engine from chassis to repair rod bearings, pinion shaft bearing or sprocket shaft bearing. See 3.3 STRIPPING MOTORCYCLE FOR ENGINE REPAIR.

It is recommended procedure to overhaul engine if removed. This includes inspecting and repairing cylinder heads, cylinders, gearcase and transmission.

ADJUSTMENT/TESTING

Flywheel End Play

Before completely disassembling crankcases, check flywheel end play.

1. After engine has been removed from chassis, securely fasten it to a stand or workbench.
2. Remove gearcase cover. See 3.18 GEARCASE COVER AND CAM GEARS (2000 models).
3. See Figure 3-124. Attach a dial indicator to gear side crankcase with indicator stem on end of gearshaft.
4. To obtain an accurate flywheel end play reading, preload sprocket shaft bearings. Create a suitable tool by welding two handles to an old engine sprocket nut. Install the nut and sprocket. Tighten to 190-210 ft-lbs (257.6-284.7 Nm).
5. Check flywheel end play.
   a. Rotate and **push** on sprocket shaft while reading dial indicator.
   b. Then rotate and **pull** on sprocket shaft while reading dial indicator.
   c. Replace bearing inner shim (See Figure 3-127.) if difference (end play) in indicator readings is not 0.001-0.005 in. (0.025-0.127 mm). Choose shim from Table 3-18.

NOTE

Use a thinner shim for less end play; use a thicker shim for more end play.

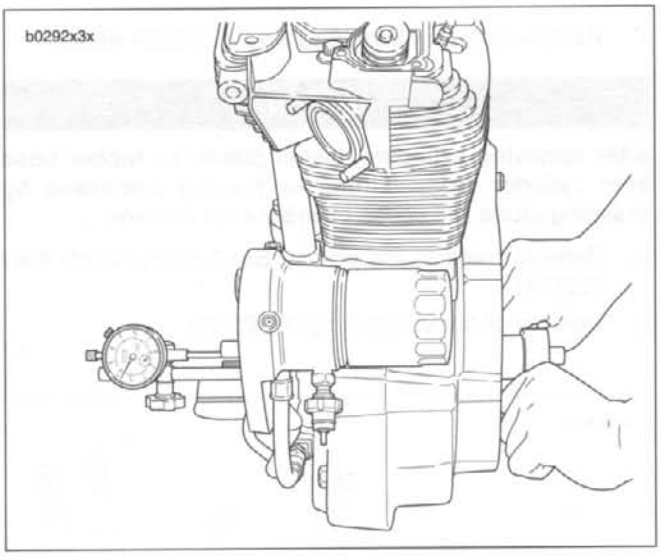


Figure 3-124. Checking Flywheel End Play

Table 3-18. Flywheel End Play Shims

PART NUMBER	THICKNESS	
	IN.	MM
9155	0.0975-0.0985	2.4765-2.5019
9142	0.0995 - 0.1005	2.5273-2.5527
9143	0.1015-0.1025	2.5781-2.6035
9144	0.1035 - 0.1045	2.6289-2.6543
9145	0.1055 - 0.1065	2.6797-2.7051
9146	0.1075 - 0.1085	2.7305-2.7559
9147	0.1095 - 0.1105	2.7813-2.8067
9148	0.1115 - 0.1125	2.8321-2.8575
9149	0.1135 - 0.1145	2.8829-2.9083

Table 3-19. Gearshaft Bearings

PART NUMBER	COLOR
24647-87	Blue
24650-87	Red
24659-87	White/Grey
24660-87	Green

DISASSEMBLY

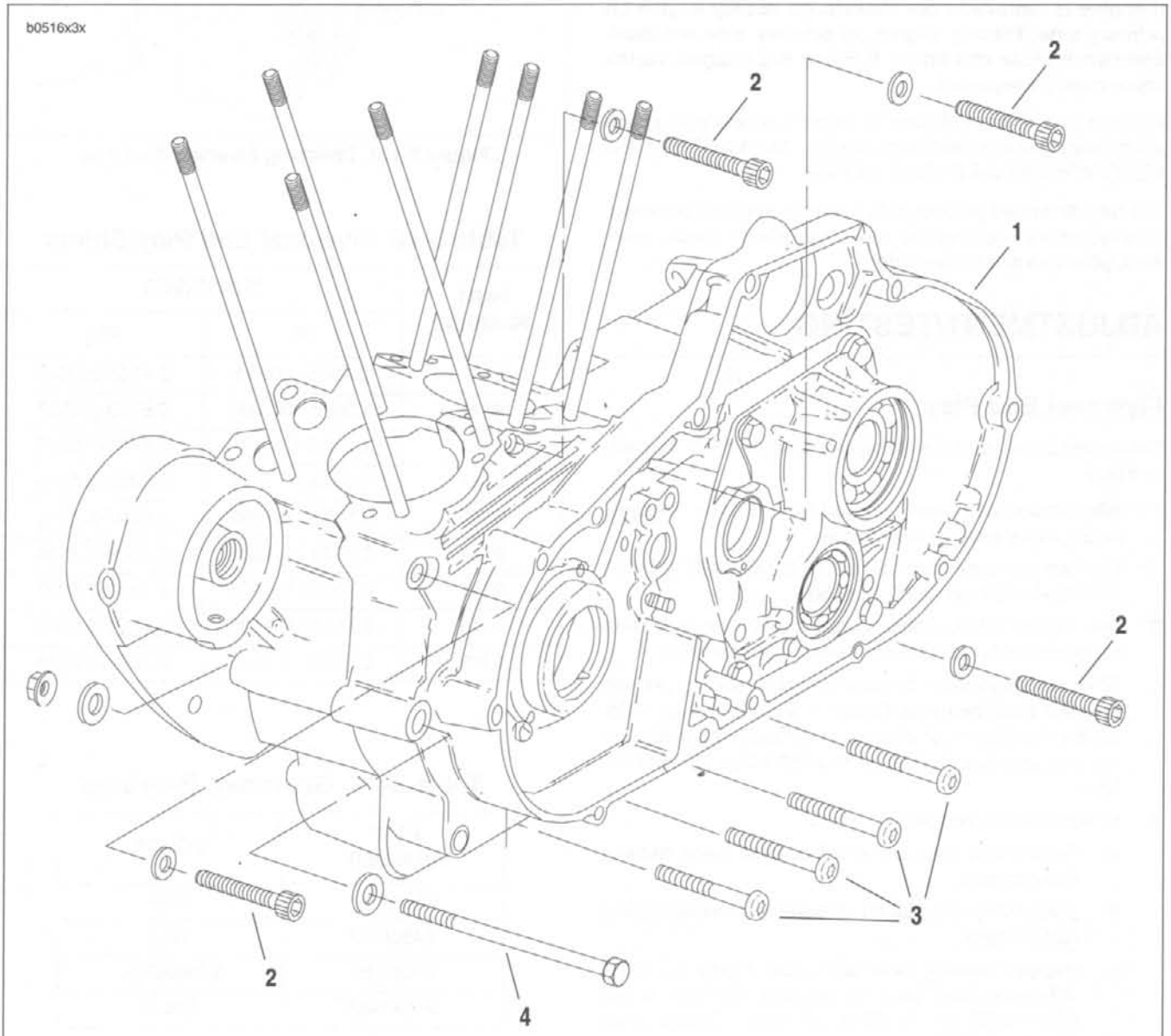
Crankcase Halves

1. Remove cylinder heads. See 3.5 CYLINDER HEAD.

CAUTION

After removing cylinders, install plastic or rubber hose over cylinder studs. Lifting or moving crankcase by grasping studs will cause cylinder stud damage.

2. Remove cylinders and pistons. See 3.6 CYLINDER AND PISTON.
3. Remove oil pump. See 3.13 OIL PUMP.
4. Remove gearcase components. See 3.18 GEARCASE COVER AND CAM GEARS (2000 models).
5. Remove primary cover and primary drive/clutch components. See PRIMARY CHAIN/DRIVE under 6.5 PRIMARY DRIVE/CLUTCH.
6. Remove starter motor. See 5.7 STARTER.
7. Remove transmission. See 6.7 TRANSMISSION CASE.
8. See Figure 3-125. Remove screws and rear engine mount bolt securing crankcase halves together.
9. Position crankcase on work bench, gearcase side up. Tap crankcase with plastic mallet to loosen top half and separate the halves.



1. **Crankcase**
2. **Upper case hex socket head screw – 5/16-18 X 2-1/2 in. long (4)**
3. **Bottom case T40 Torx bolt – 5/16-18 X 3/4 in. long (4)**
4. **Muffler mount bolt – 3/8-16 X 5-1/2 in. long (2, with washers and locknuts)**

Figure 3-125. Crankcase Hardware (Typical)

⚠WARNING

The next step requires using a press. Wear eye protection and make certain set-up is stable. The pressure involved could cause parts to "fly out" with considerable force. Inadequate safety precautions could result in death or serious injury.

10. See Figure 3-126. Mount the left crankcase half and flywheel assembly on a press table, supporting crankcase on parallel bars. Press on end of sprocket shaft with arbor press until flywheel assembly is free from crankcase half. Do not drive flywheel assembly from crankcase half as flywheels may be knocked out of alignment.

NOTE

See Figure 3-126. If it is necessary to remove either the pinion shaft bearing (11) or sprocket shaft bearing (4 and 9), proceed as follows:

11. Gearshaft bearing will remain on flywheel pinion shaft. Remove retaining ring, and bearing may be slipped off pinion shaft.

12. See Figure 3-128. Place flywheel assembly in FLYWHEEL FIXTURE (Part No. HD-44385). Pull sprocket shaft bearing with SPROCKET SHAFT INNER TIMKIN BEARING REMOVER (Part No. HD-44404) and ALL PURPOSE CLAW PULLER (Part No. HD-95635-46) using bolts in place of jaws. Insert a penny (or suitable coin) between shaft and claw puller to avoid damaging shaft.

13. See Figure 3-129. Use CRANKSHAFT BEARING TOOL (Part No. HD-94547-101) to remove sprocket shaft outer races.

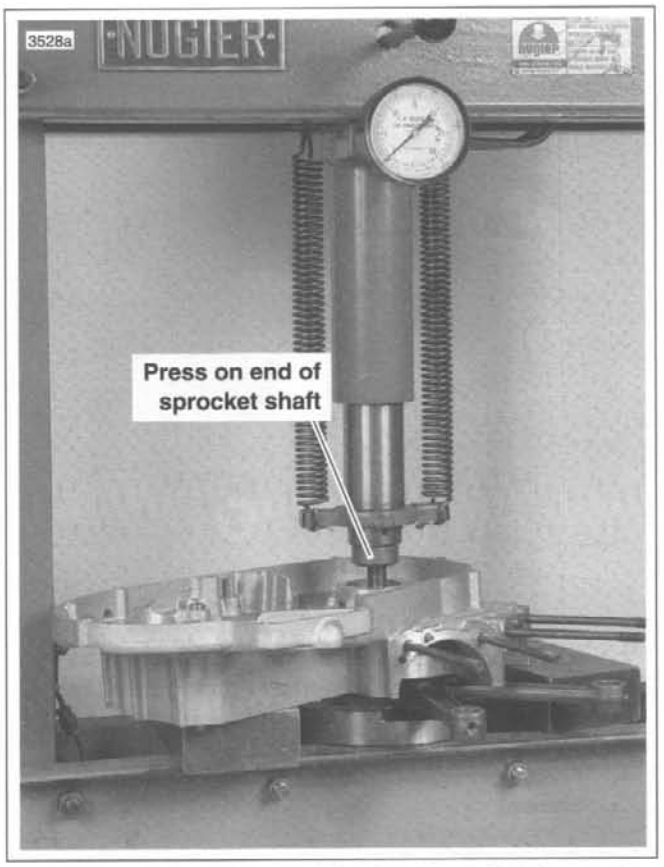


Figure 3-126. Pressing Flywheel from Crankcase

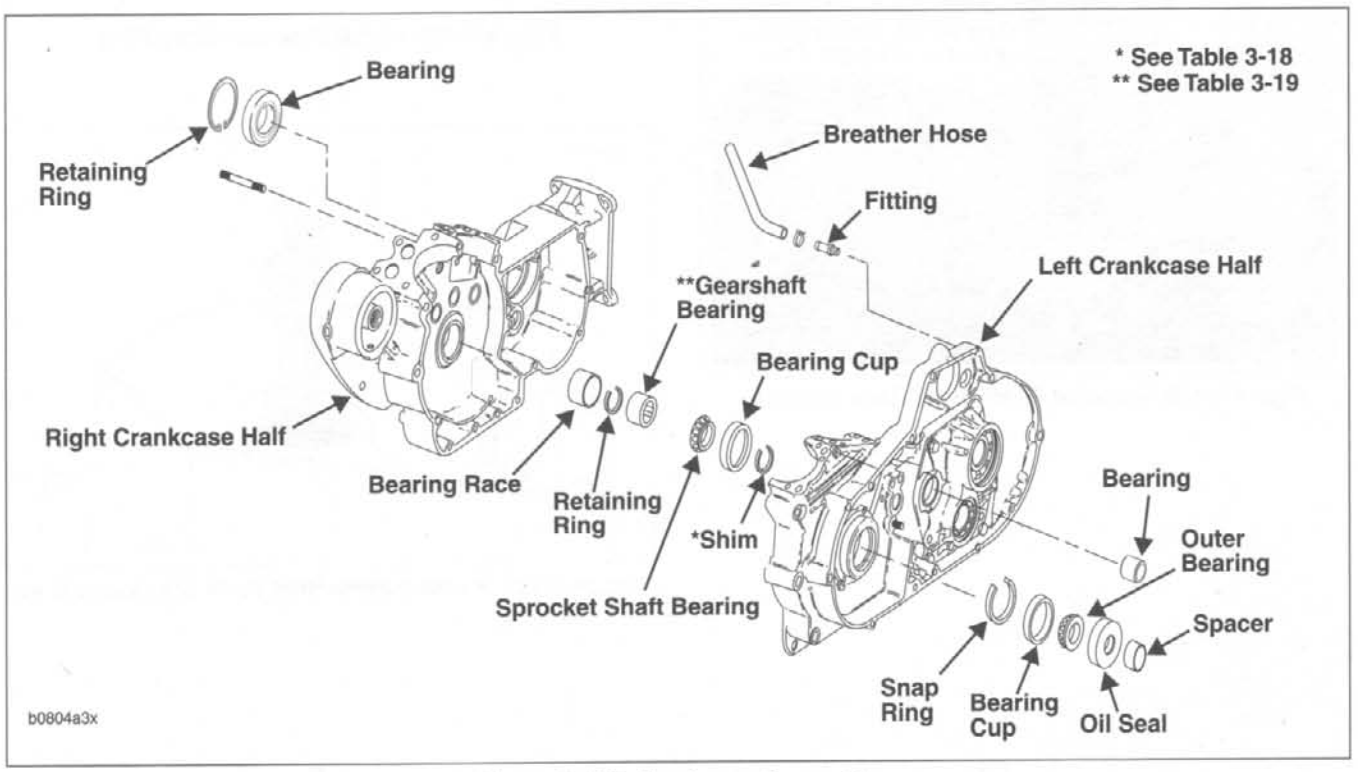
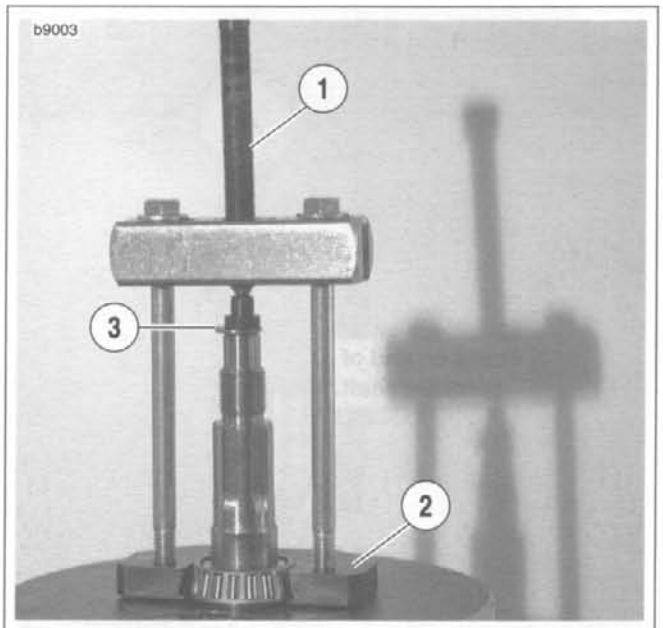


Figure 3-127. Crankcase Assembly



1. **All purpose claw puller (Part No. HD-95637-46)**
2. **Sprocket Shaft Inner Timken Bearing Remover (Part No. HD-44404)**
3. **Penny (or suitable coin)**
4. **Flywheel Fixture (Part No. HD-44385) (Not Shown)**

Figure 3-128. Removing Sprocket Shaft Inner Timken Bearing (Typical)

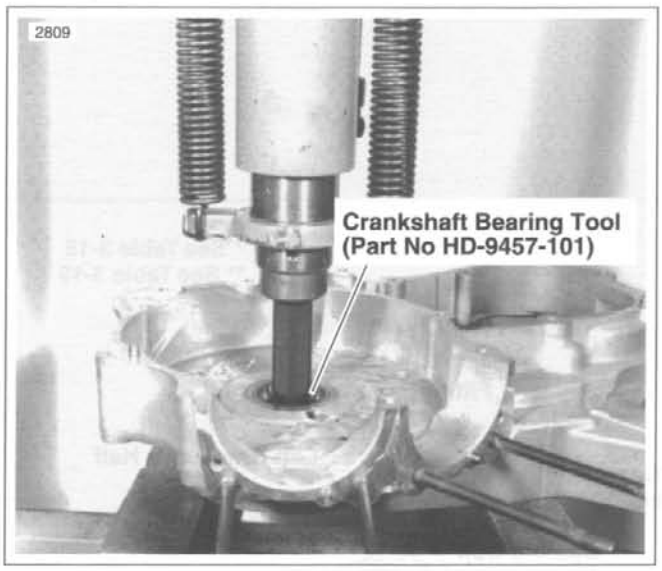


Figure 3-129. Sprocket Shaft Outer Race Removal

14. Remove crankcase retaining ring from crankcase bore.
    a. Pace the crankcase half on a flat surface with the outboard side facing up.
    b. Obtain the two TIMKEN SNAP RING REMOVER/ INSTALLER (HD-44069).
    c. See *Figure 3-130.* With the gap in the retaining ring being the 12 o'clock position, place the two claws so that the slotted sides engage the inside edge of the retaining ring at the 10 and 2 o'clock positions.
    d. Using a 9/64 inch allen head bit, tighten the screws to fix the position of the claws on the retaining ring.
    e. See *Figure 3-131.* Inserting the tips of a large retaining ring pliers (Snap-On PR-56A) into one hole in each claw, compress the retaining ring and remove it from the crankcase bore.
    f. Loosen allen head screws and remove claws from retaining ring.

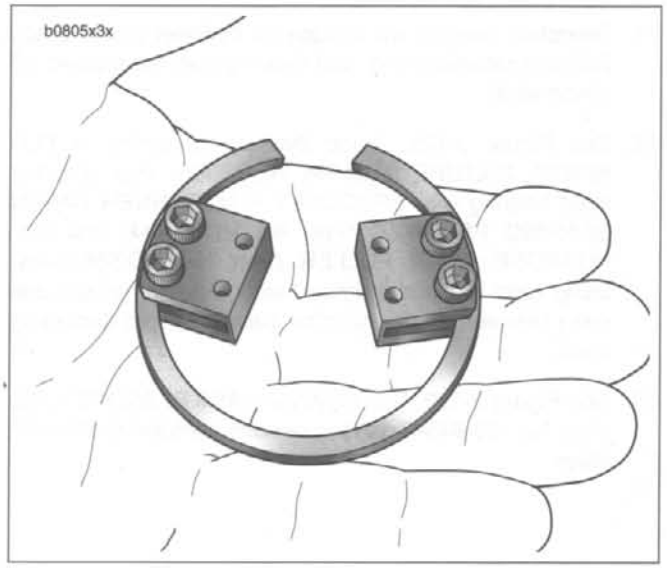


Figure 3-130. Install Claws on Snap Ring

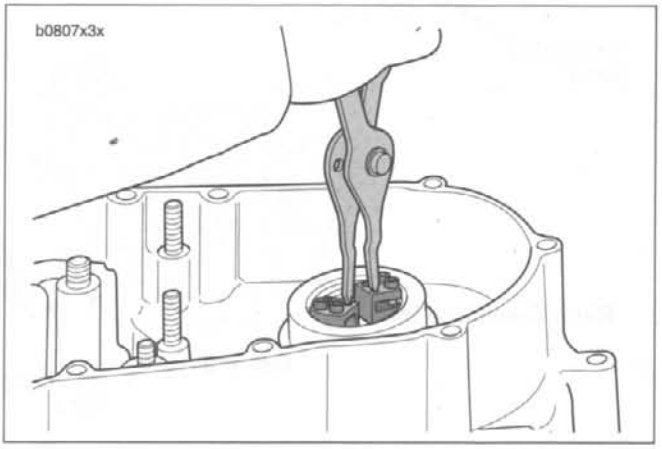


Figure 3-131. Remove Snap-Ring From Crankcase Bore

Flywheel/Connecting Rod Assembly

NOTE

If the flywheel or connecting rods need to be replaced, then they must be replaced together as one assembly. Return the flywheel/connecting rod assembly to the factory for service or replacement.

CLEANING AND INSPECTION

Wash all parts in solvent and blow dry with compressed air.

Flywheel/Connecting Rod Assembly

1. Replace the flywheel/connecting rod assembly is any of the following conditions are noted:
   - Connecting rods are bent or twisted.
   - Connecting rods do not fall under their own weight or are in a bind.
   - The crankshaft (roller) bearing inner race is burnelled, burnt, scored, blued or damaged.
2. Inspect connecting rods for correct free play.
   a. Holding the shank of each rod just above the bearing bore, pull up and down on the connecting rods. Any discernible up and down movement indicates excessive lower bearing clearance. Replace the flywheel/connecting rod assembly.
3. See Figure 3-132. Check connecting rod side play.
   a. Insert a feeler gauge between the thrust washer and the outboard side of the connecting rod.
   a. Replace the assembly if the rod side play exceeds 0.030 inch (0.762 mm).

Fitting Sprocket Bearings

If flywheel end play is within tolerance, and if tapered roller bearings and races pass visual check and have no apparent wear, the same set may be reinstalled. Make certain all parts of bearing are installed in exactly the same order in which they were removed. If any part of bearing assembly is worn, entire assembly should be replaced.

Fitting Pinion Bearings

See Figure 3-127. A pressed-in bushing in the right crankcase half is the outer race. The inner race is pressed on the pinion shaft.

See Figure 3-135. To remove pinion shaft inner race, use TWO CLAW PULLER (Part No. HD-97292-61), CENTER CAP (Part HD-95652-43A), and BEARING SEPARATOR (SNAP-ON TOOLS Stock No. CJ950). Apply heat to race to aid removal. Four sizes of pinion bearings are available. Pinion bearing selection at the factory, during engine rebuild, or replacement of crankcase set or flywheel assembly is based on the largest measured outside diameter (OD) of the inner race and the smallest measured inside diameter (ID) of the outer race (crankcase bushing). A running clearance of 0.0002-0.0008 in. (0.0051-0.0203 mm) is established during crankcase set or flywheel assembly replacement and engine rebuild.

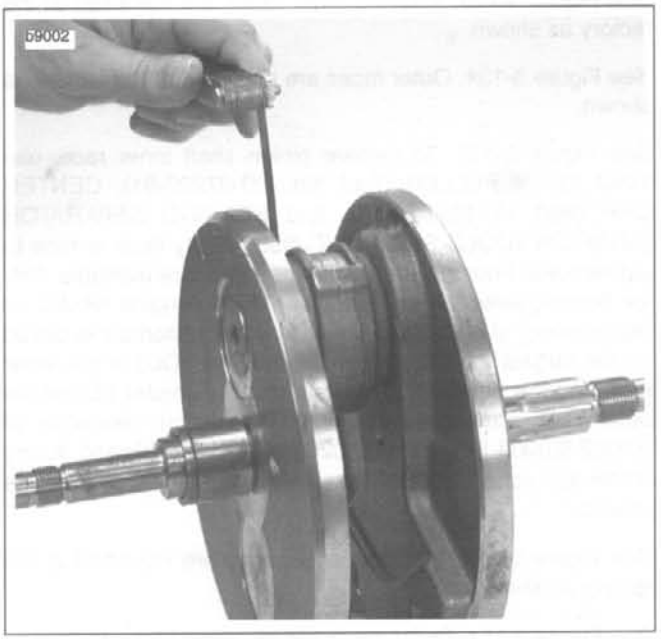
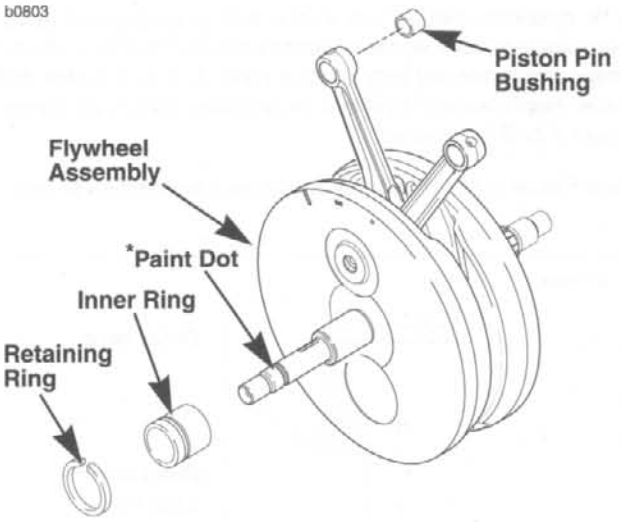


Figure 3-132. Checking Connecting Rod Side Play



RACE OD	CLASS	IDENTIFICATION*
1.2498-1.2500 in. (31.7449-31.7500 mm)	A	White
1.2496-1.2498 in. (31.7398-31.7449 mm)	B	Green

*** Paint dot on end of spline**

SERVICE WEAR LIMIT: 1.2492 in. (31.7297 mm)

Figure 3-133. Low Inertia Flywheel and Connecting Rod Assembly/Factory Inner Race Sizes

See Figure 3-133. Installed inner races are identified at the factory as shown.

See Figure 3-134. Outer races are identified at the factory as shown.

See Figure 3-135. To remove pinion shaft inner race, use TWO CLAW PULLER (Part No. HD-97292-61), CENTER CAP (Part HD-95652-43A), and BEARING SEPARATOR (SNAP-ON TOOLS Stock No. CJ950). Apply heat to race to aid removal. Four sizes of pinion bearings are available. Pinion bearing selection at the factory, during engine rebuild, or replacement of crankcase set or flywheel assembly is based on the largest measured outside diameter (OD) of the inner race and the smallest measured inside diameter (ID) of the outer race (crankcase bushing). A running clearance of 0.0002-0.0008 in. (0.0051-0.0203 mm) is established during crankcase set or flywheel assembly replacement and engine rebuild.

See Figure 3-133. Installed inner races are identified at the factory as shown.

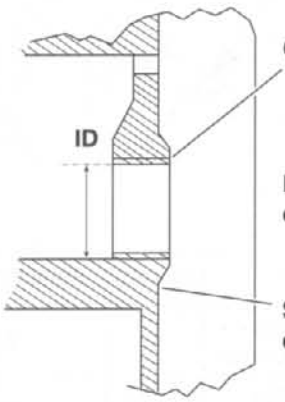
See Figure 3-134. Outer races are identified at the factory as shown.

NOTE

The different sizes of crankcase sets and flywheel assemblies will not have separate part numbers. That is, a replacement crankcase set may have a class 1, 2 or 3 pinion outer race. Replacement flywheel assemblies will have either a class A or B inner race.

See Figure 3-137. Pinion bearings are identified as shown.

b0176x3x



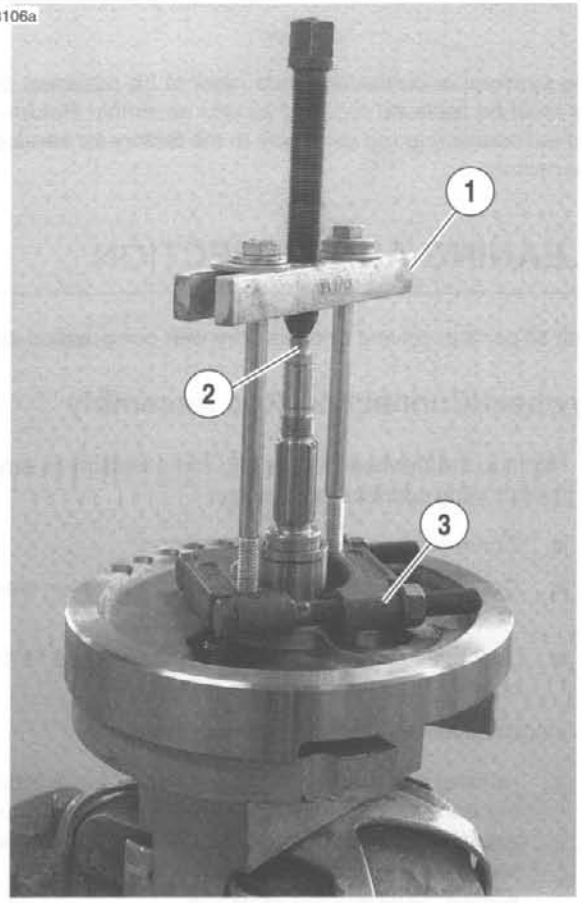
RACE ID	CLASS NO.	STAMPED IDENTIFICATION*
1.5646-1.5648 in. (39.7408-39.7459 mm)	1	1
1.5648-1.5650 in. (39.7459-39.7510 mm)	2	2
1.5650-1.5652 in. (39.7510-39.7561 mm)	3	3

*** Stamped number inside crankcase near race**

SERVICE WEAR LIMIT: 1.5672 in. (39.8069 mm)

Figure 3-134. Factory Outer Race Sizes

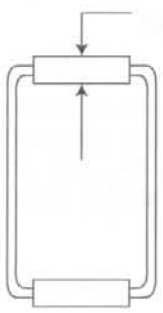
3106a



1. **Puller (Part No. HD-97292-61)**
2. **Center cap (Part No. HD-95652-43A)**
3. **Bearing separator (Snap-On Part No. CJ950)**

Figure 3-135. Pulling Pinion Shaft Inner Race (Typical)

b0065x3x



ROLLER OD (A)	IDENTIFICATION*
Largest	Red
	Blue
	White (Grey)
Smallest	Green

*** Package color**

Figure 3-136. Bearing Identification

BEARING SELECTION

Select bearings using the identification information given for inner and outer races and bearings. See Table 3-19. and Table 3-20.

NOTE

If either inner or outer race show wear, measure both races to confirm correct bearing fit.

1. Use a dial bore gauge to measure and record ID of outer race. Take four measurements on ID where bearing rollers ride.
   a. If the largest measurement is larger than 1.5672 in. (39.8069 mm) or the required lapping to remove wear marks would enlarge bore beyond 1.5672 in., continue at Step 5.
   b. If largest measurement is 1.5672 in. (39.8069 mm) or less, cover the cam bearings with masking tape to prevent debris from entering bearings. Assemble crankcase halves.

NOTE

The next step requires lapping the outer race. To keep sprocket shaft and pinion shaft bearings aligned the lap must be supported by an adaptor or pilot in the left crankcase half.

2. See LAPPING ENGINE MAIN BEARING RACES. Lap race until all wear marks are removed.
3. Measure and record ID of race at four places.
4. Check measurements against these specifications:

   Largest ID measured: 1.5672 in. (39.8069 mm) or less

   Roundness of ID: within 0.0002 in. (0.0051 mm)

   Taper: within 0.0002 in. (0.0051)

   a. If lapping increased bore ID to larger than 1.5672 in. (39.8069 mm), go to Step 5.
   b. If roundness or taper do not meet specifications, continue lapping until specifications are met.
   c. If all specifications are met, continue at Step 7 to remove and size inner race.
5. Press the outer race from the right crankcase. Press **new** outer race into crankcase flush with inside edge of cast-in insert.

   See Figure 3-138. Dimensions are shown for fabrication of tools used in pressing the outer race into or out of crankcase.
6. The **new** outer race must be lapped slightly to true and align with left case bearing and to meet the following specifications. See LAPPING ENGINE MAIN BEARING RACES.

   ID: 1.5646 - 1.5652 in. (39.7408 - 39.7561 mm)

   Roundness: within 0.0002 in. (0.0051 mm)

   Taper: within 0.0002 in. (0.0051 mm)

   Surface finish: 16 RMS

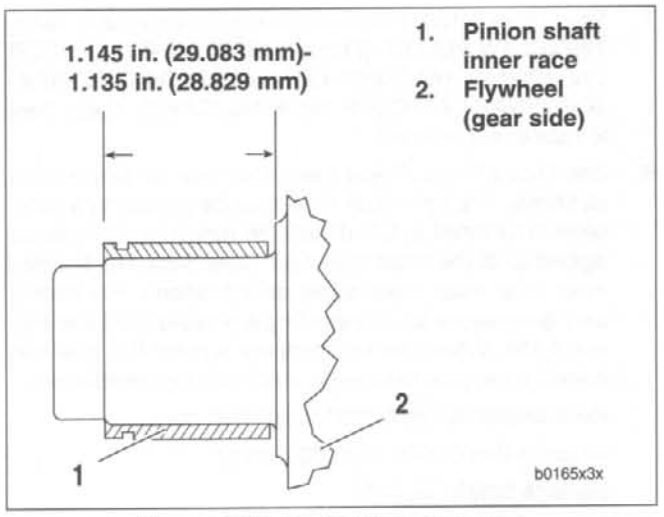


Figure 3-137. Inner Race Location

7. See Figure 3-135. Pull inner race from pinion shaft using TWO CLAW PULLER (Part No. HD-97292-61), CENTER CAP (Part No. HD-95652-43A), and BEARING SEPARATOR (SNAP-ON TOOLS Stock No. CJ950). Apply heat to race to aid removal.
8. See Figure 3-137. Press **new** inner race on pinion shaft as shown. The **new** inner race must be ground by a competent machinist to OD dimension range for the finished lapped ID of the outer race. See Table 3-20. The finished inner race must meet these specifications. For necessary dimensions for constructing a press-on tool see Figure 3-138. When the tool bottoms against the flywheel, correct inner race location is automatically established.

   Roundness: within 0.0002 in. (0.0051 mm)

   Taper: within 0.0002 in. (0.0051 mm)

   Surface finish: 16 RMS

NOTE

Always use the smallest outer race ID measurement and the largest OD inner race measurement when selecting bearings.

9. The following example illustrates how to determine the required inner race OD.
   a. See Table 3-20. For example purposes, suppose the smallest outer race ID measurement is 1.5651 in. (39.754 mm). This requires an inner race OD range of 1.2496-1.2504 in. (31.740 - 31.760 mm).

NOTE

Have machinist grind outer race to center or middle of required OD range. This will prevent grinding outer race undersize and gives a more easily achieved tolerance range.

   b. Grind inner race. Measure OD at four places. Check that specifications in Step 8 are met.
   c. For example purposes, suppose the largest inner race OD measurement after grinding is 1.2499 in. (31.747 mm) OD.
   d. With a 1.5651 in. (39.754 mm) ID outer race and a 1.2499 in. (31.747 mm) OD inner race, a blue bearing is required.

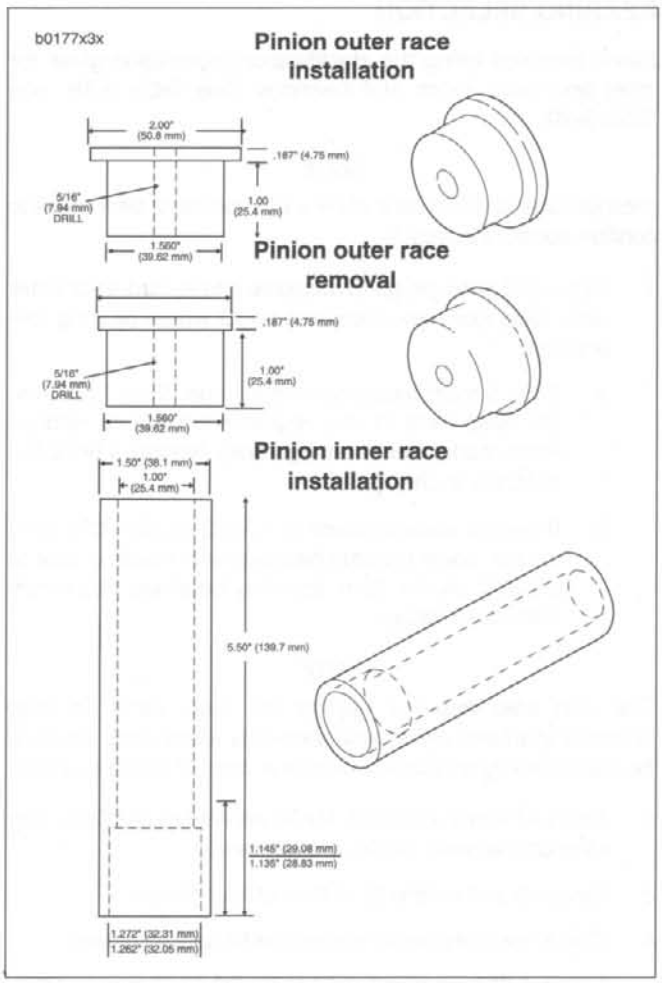


Figure 3-138. Pinion Shaft Bearing Tools

Lapping Engine Main Bearing Races

1. Secure right and left crankcase halves with three crankcase stud bolts (top center and bottom left and right). The sprocket shaft bearing outer races and large spacer must be installed in left crankcase.
2. See Figure 3-139. Obtain CRANKCASE MAIN BEARING LAPPING TOOL (Part No. HD-96710-40B). Assemble CRANKCASE MAIN BEARING LAP (Part No. HD-96718-87) to lapping handle. Assemble guide sleeve to sprocket shaft bearing bushing. Sleeves, for use with tapered bearing, are assembled to case with bearings and small spacer collar. Finger-tighten the sleeve parts.
3. Insert lap shaft with arbor assembled through pinion bearing bushing and into guide sleeve. Tighten arbor expansion collars using a length of 0.156 in. (3.962 mm) rod as spanner until arbor begins to drag. Do not adjust arbor snug in bushing or bushing will "bell," a condition where hole is larger at ends than it is in the center.
4. Withdraw arbor far enough to coat lightly with 220 grit lapping compound. Do not apply a heavy coat. Reposition lap in bushing and turn handle at moderate hand speed. Work lap back and forth in bushing, as it is revolved, to avoid grooving and tapering.

At frequent intervals, remove lap from crankcase, wash and inspect bushing. Lapping is completed when entire bushing surface has a dull, satin finish rather than a glossy, smooth appearance. If necessary, flush off lap in cleaning solvent, air dry and apply fresh, light coat of fine lapping compound.

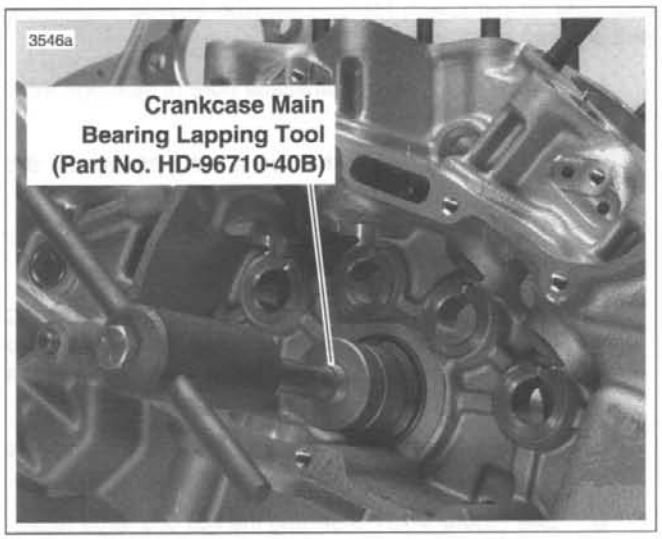


Figure 3-139. Lapping Pinion Shaft Main Bearing

Table 3-20. Pinion Shaft Bearing Selection

FACTORY STAMPED NUMBER	OUTER RACE ID	BEARING SIZE AS IDENTIFIED BY COLOR CODING										
	over 1.5672 in. 39.807 mm	Service Wear Limit Exceeded – Replace Outer Race and Resize										
	1.5670-1.5672 in. 39.802-39.807 mm											Red
	1.5668-1.5670 in. 39.797-39.802 mm										Red	Blue
	1.5666-1.5668 in. 39.792-39.797 mm									Red	Blue	White-Gray
	1.5664-1.5666 in. 39.787-39.792 mm								Red	Blue	White-Gray	Green
	1.5662-1.5664 in. 39.781-39-787 mm							Red	Blue	White-Gray	Green	
	1.5660-1.5662 in. 39.776-39.781 mm						Red	Blue	White-Gray	Green		
	1.5658-1.5660 in. 39.771-39.776 mm					Red	Blue	White-Gray	Green			
	1.5656-1.5658 in. 39.766-39.771 mm				Red	Blue	White-Gray	Green				
	1.5654-1.5656 in. 39.761-39.766 mm			Red	Blue	White-Gray	Green					
	1.5652-1.5654 in. 39.756-39.761 mm		Red	Blue	White-Gray	Green						
3	**1.5650-1.5652 in. 39.751-39.756 mm**	**Red**	**Blue**	White-Gray	Green							
2	**1.5648-1.5650 in. 39.746-39.751 mm**	**Blue**	**White-Gray**	Green								
1	**1.5646-1.5648 in. 39.741-39.746 mm**	**White-Gray**	**Green**									
INNER RACE OD (In)		**1.2496-1.2498 in.**	**1.2498-1.2500 in.**	1.2500-1.2502 in.	1.2502-1.2504 in.	1.2504-1.2506 in.	1.2506-1.2508 in.	1.2508-1.2510 in.	1.2510-1.2512 in.	1.2512-1.2514 in.	1.2514-1.2516 in.	1.2516-1.2518 in.
		31.740 31.745 mm	31.745 31.750 mm	31.750-31.755 mm	31.755-31.760 mm	31.760-31.765 mm	31.765-31.770 mm	31.770-31.755 mm	31.775-31.780 mm	31.780-31.786 mm	31.786-31.791 mm	3.791-31.796 mm
FACTORY COLOR CODE		**Green**	**White**									

ASSEMBLY

Crankcase Halves

Lubricate all parts with Harley-Davidson 20W50 engine oil, and proceed as follows:

1. Install **new** snap ring to crankcase bore (if bearings were replaced).
   a. Pace the crankcase half on a flat surface with the outboard side facing up.
   b. Obtain the two TIMKEN SNAP RING REMOVER/ INSTALLER (HD-44069).
   c. See *Figure 3-130.* With the gap in the snap ring being the 12 o'clock position, place the two claws so that the slotted sides engage the inside edge of the snap ring at the 10 and 2 o'clock positions.
   d. Using a 9/64 inch allen head bit, tighten the screws to fix the position of the claws on the snap ring.
   e. See *Figure 3-131.* Inserting the tips of a large retaining ring pliers (Snap-On PR-56A) into one hole in each claw, compress the snap ring and install in groove of crankcase bore.
   f. See *Figure 3-140.* Verify that the gap in the snap ring is centered below the oil hole at the top of the ring groove. Move snap ring if not properly centered.
   g. Loosen allen head screws and remove claws from snap ring.

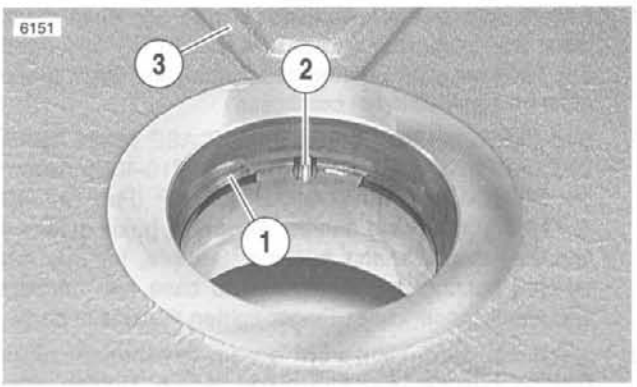
NOTE

See Figure 3-141. Use SPROCKET SHAFT BEARING OUTER RACE INSTALLATION TOOL (1, 2) (Part No. HD-39458) to install left and right outer races (4, 5) of sprocket shaft tapered roller bearings into left crankcase half (6). Always install left outer race (4) prior to installing right outer race (5) because the installer base (1) is usable only when you follow this sequence of race installation.

2. Insert "SPORTSTER" end of installer base (1) into inboard side of left crankcase half (6) bearing bore until base contacts installed retaining ring (3).
3. Position left outer race (4) over bearing bore on outboard side of left crankcase half (6).
4. Insert shaft of installer plug (2) through left outer race (4) and into installer base (1). Press race into bore until firmly seated against retaining ring (3).
5. Insert "SPORTSTER" end of installer base (1) into outboard side of left crankcase half (6) bearing bore until base contacts outboard surface of installed left outer race (4).
6. Position right outer race (5) over bearing bore on inboard side of left crankcase half (6).
7. Insert shaft of installer plug (2) through right outer race (5) and into installer base (1). Press race into bore until firmly seated against retaining ring (3).

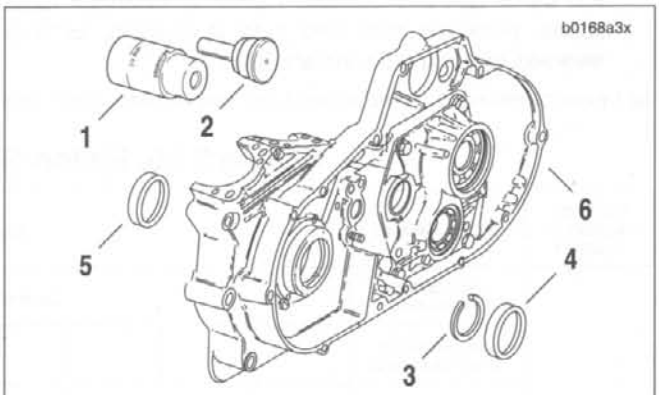
NOTE

See Figure 3-142. Use SPROCKET SHAFT BEARING/SEAL INSTALLATION TOOL (Part No. HD-42579) to install sprocket shaft tapered roller bearings and seal.



1. **Snap ring**
2. **Oil supply hole**
3. **Oil supply channel**

Figure 3-140. Snap Ring



1. **Installer base**
2. **Installer plug**
3. **Snap ring**
4. **Left outer race**
5. **Right outer race**
6. **Left crankcase half**

Figure 3-141. Installing Sprocket Shaft Bear Outer Races

8. Install inner bearing (6).

   a. Place **new** bearing, small end upward, over end of sprocket shaft.

   b. Thread pilot (1) onto sprocket shaft until pilot bottoms on sprocket shaft shoulder.

   c. Sparingly apply graphite lubricant to threads of pilot shaft to ensure smooth operation.

   d. Slide sleeve (5) over pilot (1) until sleeve contacts inner bearing race. Install Nice bearing (4), washer (3) and handle (2) on top of sleeve.

   e. Rotate handle clockwise until bearing (6) contacts flywheel shoulder. Remove tool from sprocket shaft.

9. See Figure 3-127. Install shim and outer bearing.

   a. See Figure 3-143. Carefully place crankcase half over sprocket shaft so that it rests flat on inner bearing.

   b. Slide **new** inner spacer over sprocket shaft until it contacts inner bearing race.

   c. Place **new** outer bearing, small end downward, over sprocket shaft.

   d. Assemble SPROCKET SHAFT BEARING/SEAL INSTALLATION TOOL (Part No. HD-42579) onto sprocket shaft. Follow procedure in Step 8.

   e. Rotate handle clockwise until bearing firmly contacts inner spacer. Inner and outer bearings must be tight against inner spacer for correct bearing clearance. Remove tool from sprocket shaft.

   f. Spin crankcase half to verify that flywheel assembly is free.

10. See Figure 3-144. Install **new** spacer in seal ID. With the open (lipped) side facing outward, center seal/spacer assembly over bearing bore.

CAUTION

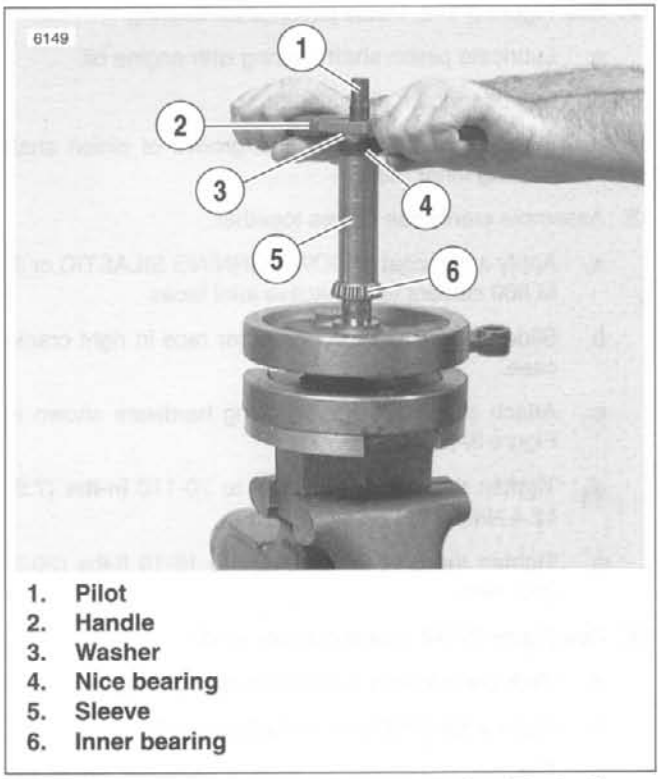
Do not remove the spacer after installation or the new seal will have to be discarded and the procedure repeated.

11. See Figure 3-145. Install bearing seal and spacer.

   a. Center seal/spacer driver (2) over seal, so that the sleeve (smaller OD) seats between seal wall and garter spring.

   b. Assemble SPROCKET SHAFT BEARING/SEAL INSTALLATION TOOL (1) (Part No. HD-42579) and SPROCKET SHAFT SEAL/SPACER INSTALLER (Part No. HD-42774) onto sprocket shaft. Follow procedure in Step 8.

   c. Rotate handle clockwise until the spacer makes contact with the bearing. Remove tool from sprocket shaft.



1. **Pilot**
2. **Handle**
3. **Washer**
4. **Nice bearing**
5. **Sleeve**
6. **Inner bearing**

Figure 3-142. Inner Bearing Installation (Typical)

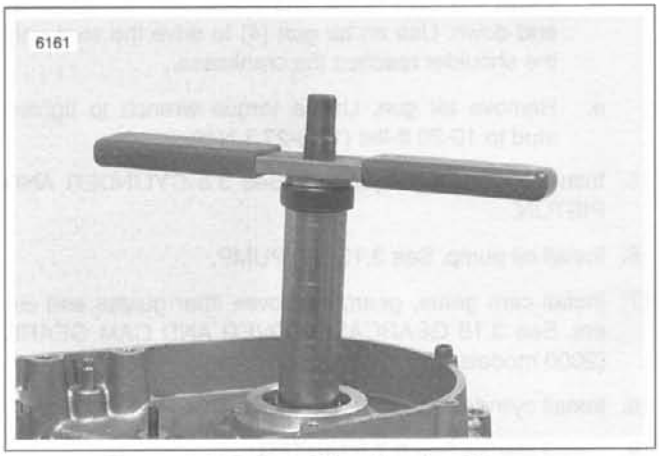


Figure 3-143. Installing Flywheel Spacer and Outer Bearing

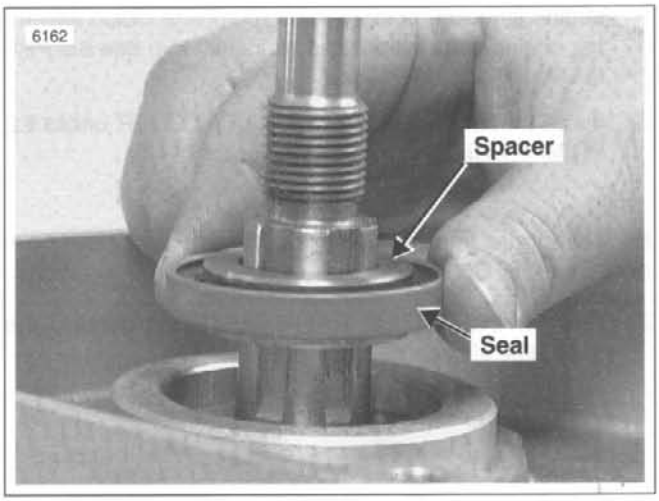


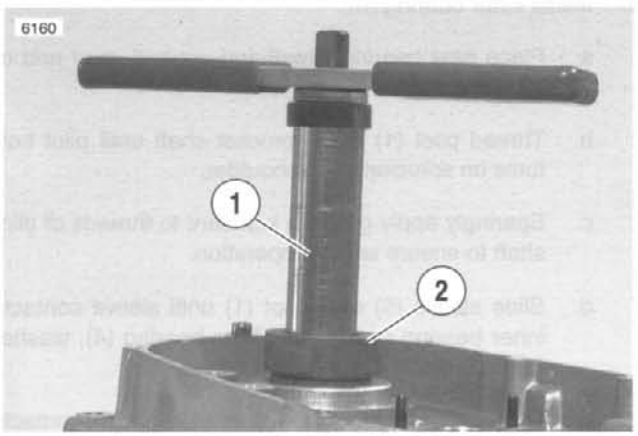
Figure 3-144. Install Spacer in Seal

12. See Figure 3-146. Install pinion shaft bearing.
    a. Lubricate pinion shaft bearing with engine oil.
    b. Slip bearing on pinion shaft.
    c. Install **new** retaining ring in groove of pinion shaft bearing inner race.
13. Assemble crankcase halves together.
    a. Apply a thin coat of DOW CORNING SILASTIC or 3-M 800 sealant to crankcase joint faces.
    b. Slide pinion shaft through outer race in right crankcase.
    c. Attach crankcase halves using hardware shown in Figure 3-125.
    d. Tighten the 1/4-in. fasteners to 70-110 **in-lbs** (7.9-12.4 Nm)
    e. Tighten the 5/16-in. fasteners to 15-19 ft-lbs (20.3-25.8 Nm).
14. See Figure 3-147. Install cylinder studs.
    a. Pack clean towels into crankcase opening.
    b. Place a steel ball into a head screw (1).
    c. The cylinder studs (2) have a shoulder (3) at the lower end. Place the end of the stud without the shoulder into the head screw.
    d. Install the stud in the crankcase with the shoulder end down. Use an air gun (4) to drive the stud until the shoulder reaches the crankcase.
    e. Remove air gun. Use a torque wrench to tighten stud to 10-20 ft-lbs (13.6-27.1 Nm).
15. Install pistons and cylinders. See 3.6 CYLINDER AND PISTON.
16. Install oil pump. See 3.13 OIL PUMP.
17. Install cam gears, gearcase cover, lifter guides and lifters. See 3.18 GEARCASE COVER AND CAM GEARS (2000 models).
18. Install cylinder heads. See 3.5 CYLINDER HEAD.
19. Install starter. See 5.7 STARTER.
20. Install transmission. See 6.13 TRANSMISSION INSTALLATION AND SHIFTER PAWL ADJUSTMENT.
21. Install all primary drive components. This includes engine sprocket, primary chain, complete clutch assembly, engine sprocket nut and mainshaft nut. See 6.5 PRIMARY DRIVE/CLUTCH.
22. Install primary cover. See PRIMARY COVER under 6.2 PRIMARY CHAIN.

NOTE

Be sure to refill transmission to proper level with fresh lubricant. See 1.12 CLUTCH.

23. See 3.4 INSTALLING THE ENGINE and perform the applicable steps.



1. **Bearing/seal installer (Part No. HD-42579)**
2. **Seal/spacer installer (Part No. HD-42774)**

Figure 3-145. Install Bearing Seal/Spacer

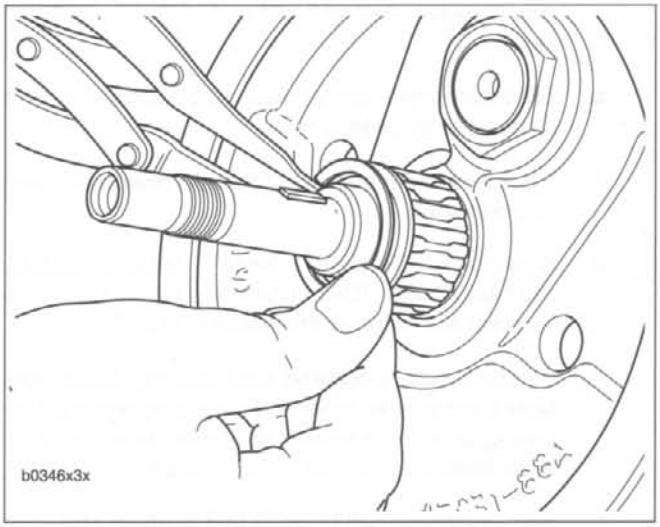
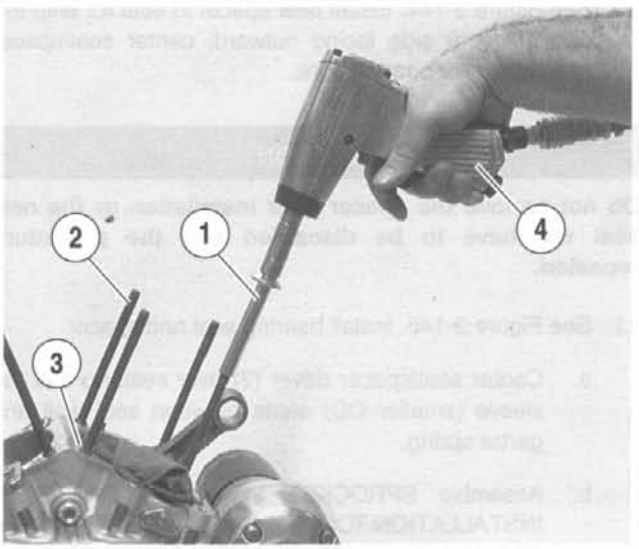


Figure 3-146. Pinion Shaft Bearing



1. **Head screw with ball inside**
2. **Cylinder stud**
3. **Shoulder on cylinder stud**
4. **Air gun**

Figure 3-147. Cylinder Studs